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GROUND WATER IN LOUISIANA

WATER RESOURCES BULLETIN No. 1

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In cooperation with the

UNITED STATES GEOLOGICAL SURVEY

Water Resources Bulletin No. 1

GROUND WATER IN LOUISIANA

by

J. R. ROLLO

Engineer, U. S. Geological Survey

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DEPARTMENT OF CONSERVATION

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Geology

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CONTENTS

	Page
ABSTRACT	1
INTRODUCTION	3
Purpose and scope	3
Methods of investigation	4
Acknowledgments	4
ELECTRICAL LOGS	5
GEOLOGIC UNITS AND THEIR WATER-BEARING CHARACTERISTICS	9
General Stratigraphy	9
Structure	10
Principles of occurrence of ground water	16
Water-table and artesian conditions	16
Recharge, discharge, and movement	16
Quality of water	17
General availability of fresh ground water	18
Cretaceous system	19
Tertiary system	19
Midway group	19
Wilcox group	20
Claiborne group	24
Cane River formation	24
Sparta sand	26
Cook Mountain formation	30
Cockfield formation	30
Jackson and Vicksburg groups	34
Miocene series	35
Pliocene series	38
Quaternary system	41
Quaternary valley deposits	42
Quaternary upland deposits	43
Terraced deposits of northern Louisiana	43
Coastwise terraces and their subsurface equivalents	44
SUMMARY OF GROUND-WATER AVAILABILITY	47
Altitude of the base of fresh water	47
Quantity and quality, by regions	49
SELECTED REFERENCES	77
INDEX	83

ILLUSTRATIONS

Page

Plate 1. Generalized geological map of Louisiana.....In envelope

2. Fence diagram showing subsurface geology of Louisiana .....In envelope

3. Map showing, by contours, the altitude of the base of fresh ground water (chloride content less than 250 ppm) in Louisiana.....In envelope

4. Map showing the general availability of ground water in Louisiana.....In envelope

Figure 1. Idealized electrical log showing typical deflections for beds of clay and sand containing waters of different quality 5

2. Map showing major structural features affecting Louisiana 11

3. Map showing locations of 131 salt domes in Louisiana; names and approximate locations are shown in table 2 13

4. Map showing by contours the altitude of the base of fresh ground water in the vicinity of Rayburns salt dome, Bienville Parish 14

5. Geologic section of Rayburns salt dome, Bienville Parish 15

6. Typical electrical-log sections of the Midway group, (A) northwestern Louisiana and (B) north-central Louisiana 20

7. Typical electrical-log sections of the Wilcox group, (A) Caddo Parish, (B) Union Parish, and (C) Winn Parish 22

8. Map showing the approximate area where rocks of The Wilcox group contain fresh water 23

9. Typical electrical-log sections of the Claiborne group, (A) central Louisiana and (B) northeastern Louisiana 25

10. Map showing the approximate areas where rocks of the Sparta sand of the Claiborne group contain fresh water 27

11. Map showing the approximate areas where rocks of the Cockfield formation of the Claiborne group contain fresh water 32

12. Typical electrical-log sections of the Jackson and Vicksburg groups, (A) where overlain by alluvial deposits and (B) as normally overlain by Miocene sediments 34

Page

13. Composite electrical-log section of Miocene, Pliocene, and Quaternary deposits 36

14. Map showing the approximate area where rocks of the Miocene series contain fresh water 37

15. Map showing the approximate area where rocks of the Pliocene series contain fresh water 39

16. Map showing the approximate area where rocks of the Quaternary system contain fresh water 42

Tables 1-10 .....following 55

Table 1. Generalized post-Cretaceous stratigraphic column for Louisiana..... 57

2. Names and locations of salt domes shown on figure 3..... 59

3. Chemical analyses of water from sands of the Wilcox group..... 63

4. Chemical analyses of water from the Sparta sand of the Claiborne group..... 64

5. Chemical analyses of water from sands of the Cockfield formation of the Claiborne group..... 65

6. Chemical analyses of water from sands of the Miocene series 66

7. Chemical analyses of water from sands of the Pliocene series 67

8. Chemical analyses of water from Quaternary valley deposits 68

9. Chemical analyses of water from Quaternary upland deposits 69

10. Oil-test and water wells shown on plate 2..... 70

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Baton Rouge, Louisiana

GROUND WATER IN LOUISIANA

By J. R. Rollo

WATER RESOURCES BULLETIN NO. 1 August 1960

ABSTRACT

Fresh ground water is available in Louisiana in rocks which range in age from Paleocene to Recent. The Wilcox group of Paleocene and Eocene age contains the oldest aquifers bearing fresh water in Louisiana. This group contains fresh water in northwestern Louisiana, where it crops out or is near the surface. Water-bearing sands in the Wilcox group generally are fine grained and lenticular, which preclude high yields from wells. The maximum recorded yield of a well in these deposits is about 500 gpm (gallons per minute). Water from sands in the Wilcox generally is soft but commonly contains excessive amounts of iron. The Sparta sand of Eocene age yields fresh ground water to wells throughout much of northern Louisiana. Wells completed in this formation yield as much as 2,000 gpm. The water generally is soft but contains excessive amounts of iron in some places. The Cockfield formation of Eocene age yields fresh ground water to wells in north-central and northeastern Louisiana. Sands in this formation generally are finer grained and thinner than those of the aquifers in the Sparta sand; consequently, well yields are less. The largest recorded yield of a well in the Cockfield formation is about 700 gpm. The water generally is

potable; however, in places highly colored water occurs in the upper part of the formation. Miocene deposits thicken wedgelike from central Louisiana and southern Mississippi toward the Gulf of Mexico and contain fresh ground water to a depth of as much as 3,550 feet below the land surface. This represents the greatest known depth of fresh ground water in Louisiana. The water from Miocene deposits generally is soft and has a low iron content. Pliocene sediments also thicken toward the Gulf of Mexico, and wells in southeastern Louisiana have flowed as much as 3,200 gpm. Pliocene deposits in southeastern Louisiana yield soft water with a low iron content. The water generally is soft in southwestern Louisiana, but is slightly colored in some places and may have an excessive iron content. Deposits of Quaternary age blanket much of Louisiana and in many places the deposits contain thick beds of sand and gravel. Quaternary deposits yield about two-thirds of the ground water pumped in Louisiana. Yields of wells commonly are very large, as much as 6,000 gpm. Water from these deposits generally is hard and contains excessive amounts of iron, but high yields of wells and low water temperature make these sediments a valuable source of water for industrial cooling and irrigation.

In Louisiana the altitude of the base of occurrence of fresh ground water ranges from more than 200 feet above sea level, in the northwestern part of the State, to about 3,500 feet below sea level, in the southeastern part. The depth to which fresh water occurs decreases abruptly southward along a general east-west line, between 30° and 30½° north latitude. Along this line, which marks the southern limit of fresh-water flushing of Miocene and Pliocene deposits, the depth to which fresh water occurs may decrease by as much as 2,500 feet in a distance of 5 miles.

INTRODUCTION

PURPOSE AND SCOPE

Ground-water investigations began in Louisiana in 1938, when the U.S. Geological Survey and the Louisiana Geological Survey entered into a cooperative program to study the ground-water resources of the State. The Louisiana Department of Public Works became a party to the cooperative program in 1943. Information has been collected on water wells and the occurrence and quality of ground water, and thousands of electrical logs of oil and gas test wells have become available. Numerous areal reports on the ground-water resources of the State have been prepared from this information. These reports provide information concerning their respective areas but do not provide State-wide correlation of information on the ground water resources of Louisiana. It is the purpose of this report to summarize available data on the general availability of fresh ground water in the State, to establish a regional framework within which the detailed investigations may gain more significance, and to provide general ground-water information on those areas which have not been studied in detail.

This report was prepared in response to numerous requests for data on the general availability of ground water throughout the State. It should be of particular interest to those responsibile for planning the development of ground-water resources. For example, information is given that will aid industries in the preliminary investigation of potential plant sites, water well drillers, and oil companies and state agencies. Moreover, the information will aid in the design of wells that will prevent contamination of aquifers containing fresh water by those containing salt water.

The scope of this report is limited to a general discussion of electrical logs, geology, and ground water. The use of electrical logs in ground water and geologic investigations especially as a basis for distinguishing between fresh and salt water is summarized briefly. The subsurface geology of Louisiana is reviewed, to the probable maximum

depth of fresh ground water, and illustrated by a fence diagram. The occurrence of fresh ground water is discussed and illustrated by geologic unit and by maps showing the altitude of the base of fresh water and the quantity and quality of ground water generally available throughout the State. No attempt has been made to discern and discuss localized anomalies because this would exceed the scope of this study.

METHODS OF INVESTIGATION

Data used in this report are primarily from electrical logs, chemical analyses of ground water, records of water wells, and reports on the geology and ground-water resources of Louisiana and adjacent states.

Electrical logs were the principal source of data used to determine formational boundaries, the altitude of the base of fresh ground water, and the general availability of ground water. Chemical analyses were used as an aid in the interpretation of electrical logs and to determine the quality of water in each geologic unit. Yields of wells in each aquifer were determined from water-well records.

ACKNOWLEDGMENTS

Many water-well contractors, industries, municipalities, and individuals contributed to the basic data essential to this report. Special appreciation is given Mr. Leo W. Hough, State Geologist, for making available the electrical logs of oil-test wells drilled throughout the State, as these logs form the principal base of this study.

ELECTRICAL LOGS

Electrical well logging is a method of determining the electrical properties—spontaneous potential and resistivity—of subsurface deposits and their contained fluids. A conventional electrical log is a graph of these properties at different depths below some reference point; the spontaneous potential is recorded on the left side of the graph, and one or more resistivity curves are recorded on the right. Figure 1 is an idealized example of the deflections

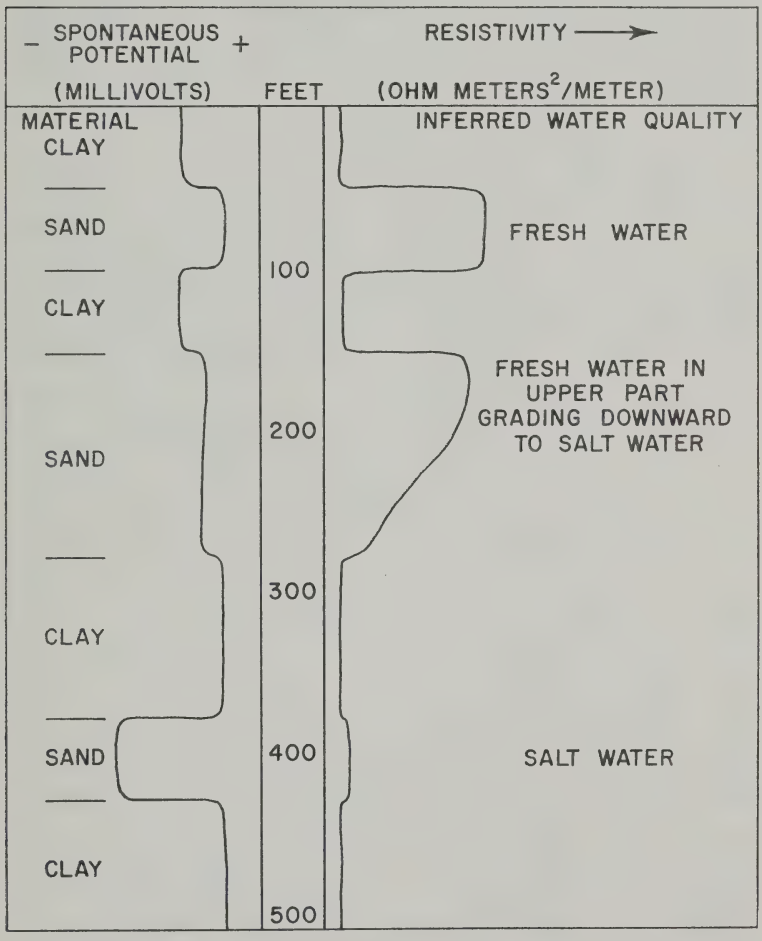

Figure 1. Idealized electrical log showing typical deflections for beds of clay and sand containing waters of different quality.

that would be produced where the formations penetrated in the borehole are saturated with the fluids indicated on the figure.

The spontaneous potential curve is a measure of the electromotive force generated at the contact between two different materials, such as clay and sand, in a conductive fluid and is recorded on the electrical log in millivolts. Typical positive deflections of the spontaneous potential curve, where the resistivity of the drilling fluid is less than that of the formational water, are shown opposite the fresh-water-bearing sands on figure 1. If the resistivity of the drilling fluid is greater than that of the formational water, the deflection of the spontaneous potential curve would be negative opposite fresh-water-bearing sands.

Depending on the application of the electrical log and the logging equipment, one or more resistivity curves may be recorded. Commercial electrical logs usually have four resistivity curves—the short-normal, the amplified short-normal, the long-normal, and the lateral. These curves are a measure of the resistivity of the formation and its contained fluids at various depths of investigation from the well bore. The short-normal and amplified short-normal curves are identical except for the horizontal scale. They record the resistivity of the zone immediately adjacent to the well bore, which, in permeable beds, may be influenced considerably by invasion of drilling fluids. They provide more detailed information on thin-bedded strata than do the other resistivity curves. The long-normal curve generally is affected less than the short-normal curve by the invasion of drilling fluids because it records the resistivity of the formation at greater distances from the well bore. This curve generally will give the best value of formational resistivity in relatively thin formations, but which have a thickness greater than the spacing of the electrodes. The lateral curve reflects a greater depths of investigation than the other resistivity curves because of the wider electrode spacing. The resistivity it records essentially is unaffected by the invasion of drilling fluids under most conditions. In thick formations the lateral curve gives the best value of formational resistivity. It is affected to some degree by bed thickness and does not accurately record

the resistivity of beds with a thickness less than the electrode spacing.

The spontaneous potential and resistivity curves are used to determine contacts between lithologic units and to estimate the chemical quality of the formation water. Drillers' logs, chemical analyses of water from the same stratigraphic unit, drill cuttings, surface and bottom-hole temperatures, hole diameter, and resistivity of the drilling fluid also are valuable in interpreting electrical logs. The quality of formational water may be interpreted erroneously without these data. For example, the quality of formational waters at Baton Rouge and New Orleans differs radically, even though the electrical properties recorded on electrical logs from the two areas are similar. Generalized electrical logs are illustrated under the discussion of each post-Cretaceous geologic unit. These logs consist of the spontaneous potential and long-normal resistivity curves and, represent the general appearance of the various formations as they appear on electrical logs. Many of the correlations in this report are based on the electrical properties shown on these logs.

GEOLOGIC UNITS AND THEIR WATER-BEARING CHARACTERISTICS

GENERAL STRATIGRAPHY

In the overall aspect the post-Cretaceous geology of Louisiana is rather simple. Fisk (1944, p. 59) described the general sedimentary history in the following manner:

> . . . The history of coastal plain sedimentation has been one of a general slow outbuilding of shallow-water delta deposits into the sea. This gradual encroachment of the land upon the Gulf of Mexico has been punctuated by long periods of slackened sedimentation during which the sea advanced far inland across low-lying deltaic plains. The widespread marine deposits laid down during these transgressions of the sea, together with thin marine facies incorporated in the advancing deltaic masses, contain fossils which make it possible to correlate strata of widely separated areas.

He stated also (1944, p. 61):

> . . . The deltaic pattern of sedimentation is the dominant feature of Tertiary deposition. Thick ladles of sediment overlap seaward and are separated by thinner, widespread marine deposits.

However simple the regional geology may appear, detailed investigation reveals a complex system of deltaic deposits in which paleontological data are necessary to correlate some formations. Therefore, only geologic formations that may be correlated on the basis of lithology, without the use of paleontological data, are shown in the post-Cretaceous stratigraphic column (table 1). Other units of the section given in table 1 are divided on the basis of typical lithology into series and groups. Because of the similarity of water-bearing characteristics of these geologic units, they may be considered a hydrologic entity, even though locally they may contain several aquifers. The surface and subsurface relations of these geologic units are illustrated by a generalized geological map of Louisiana (pl. 1) and by a fence diagram (pl. 2).

Correlation of Miocene and younger sediments is difficult because of their lenticularity. The top of the Miocene in southern Louisiana is considered in this report to be the top of the faunal zone containing the brackish water clam *Rangia johnsoni*. This zone is not distinctive

lithologically and thus cannot be correlated regionally using electrical logs. The top of the Miocene, as used in this report, was modified from a contour map by Fisk (1944, fig. 68). A thick section of sediments, assigned to the Pliocene in southwestern Louisiana by Jones (1954, p. 56-61), lies between the faunal zone and the base of gravelly deposits that are Pleistocene in age. Although the correlations made by Jones are generally followed in this bulletin, the author believes that the Pliocene age assignment should be left in question until verified by adequate faunal evidence. The gravelly deposits of the Pleistocene are not continuous but grade into sand toward the coast. Although gravelly units may not be continuous over wide areas, the zone that contains the gravel normally may be traced long distances using electrical logs.

STRUCTURE

The major structural features of Louisiana are the north-south-trending Mississippi structural trough and the east-west-trending Gulf Coast geosyncline. Subordinate to these downwarps, but of major importance, are the Monroe and Sabine uplifts of northern Louisiana and the southern Mississippi uplift, which affects northeastern Washington Parish. These major structural features as mapped by Fisk (1944, fig. 5) and Bornhauser (1958, fig. 1) are shown in figure 2. Fisk (1944, p. 64) described the general relations of these features as follows:

> . . . The structural features developed slowly while the deltaic masses were being built out in the gulf or into its late Mesozoic and early Tertiary extension within the Mississippi Embayment area. Sinking of the earth's crust in the downwarped areas progressed simultaneously with the accumulation of sediment; the existing axes of downwarping directly follow the lines of maximum thickness. Uplift of the limbs of the structural trough progressed landward as the axial areas sank and it appears, therefore, to have taken place as an isostatic adjustment to downbowing. The principal effect of the uplift has been to raise gradually the landward margins of the troughs and to cause the incision of the drainage.

Thus, subsidence accompanied by sedimentation has been dominant since late Mesozoic time. This subsidence has been localized in the Mississippi structural trough and the Gulf Coast geosyncline.

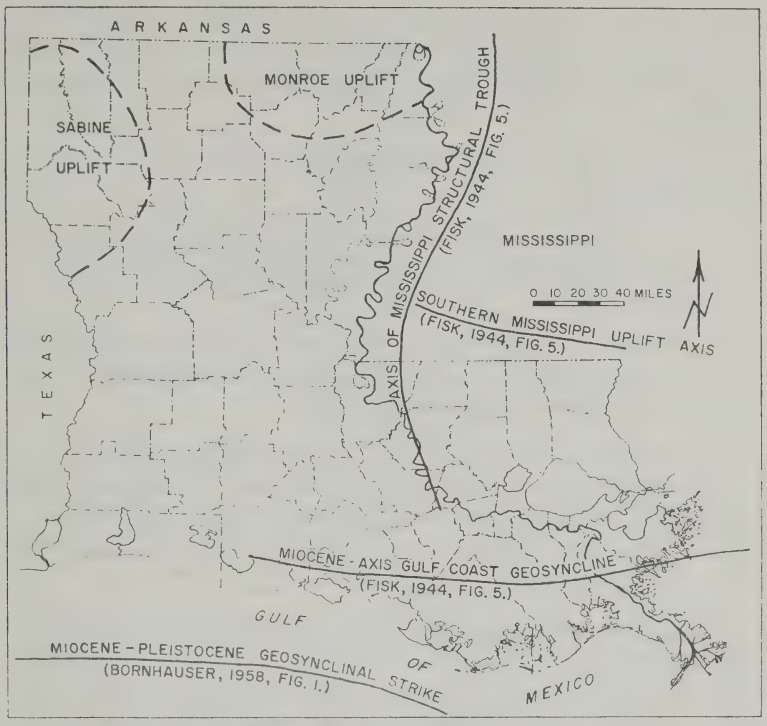

Figure 2. Map showing major structural features affecting Louisiana.

The Mississippi structural trough is indicated on the surface by progressively older formations cropping out on the eastern and western flanks of the trough. The axis of the trough lies east of and roughly parallel to the Mississippi River (fig. 2). Sediments in the trough thicken to the south and eventually merge with those of the Gulf Coast geosyncline (pl. 2).

The Gulf Coast geosyncline has little or no surface expression. Its location was determined by deep drilling for oil in the coastal areas of Louisiana and adjacent states. The maximum thickness of sediments in this trough is unknown. However, estimates that the geosyncline may contain 40,000 feet of sediments (Howe, 1936) probably are not excessive. An oil-test well near the mouth of the Mississippi River was drilled to a depth of 22,559 feet and failed to completely penetrate deposits of Miocene age.

Bornhauser (1958) concluded, on the basis of recent evidence, that the Miocene-Pleistocene axis of the geosyncline was farther seaward than had hitherto been supposed (fig. 2).

The Sabine uplift was described by Murray (1945, p. 51) as follows:

> . . . The Sabine uplift is a relatively flat-topped, roughly quadrate dome approximately 80 miles long and 65 miles wide situated in northwestern Louisiana and northeastern Texas.

Its presence is indicated on the surface by the exposure of older rocks at the center that are surrounded by outcrops of progressively younger rocks.

The Monroe uplift is east of the Sabine uplift and is separated from it by a small syncline. Subsurface data shows a flattening of the dip of Mesozoic and lower Eocene deposits and a thinning of the deposits over the top of the uplift (Fisk, 1944, p. 65).

The south flank of the southern Mississippi uplift is marked by a sharp increase in the regional dip called the Mobile-Tunica flexure (Howe, 1936, p. 20). The structurally high position of Wilcox strata caused by the Mobile-Tunica flexure is illustrated on plate 2 in the vicinity of well 143. The Sparta and Cockfield formations are missing from the Claiborne group in this area. The correlations shown on plate 2 are based on sections published by the South Louisiana Geological Society (Progress report, 1945, section E-E′).

Figure 3 is a map prepared by the Louisiana Geological Survey showing the location of 131 salt domes in the State. Some of these domes are deep seated and have no effect on the occurrence of fresh ground water, but domes that penetrate to or near the land surface have a pronounced effect. Rayburns dome (8 on fig. 3) is an excellent example of the complex effect that salt domes may have on the occurrence of fresh ground water. The altitude of the base of fresh ground water at Rayburns dome and the approximate outline of the salt near its apex is shown on figure 4. A geologic section along line A-A′ (fig. 4) is shown on figure 5. These illustrations indicate that

Figure 3. Map showing locations of 131 salt domes in Louisiana; names and approximate locations are shown in table 2.

fresh water reaches a greater depth on the flanks of the dome than in the surrounding area and that fresh water is absent altogether over the apex of the dome. The intrusion of the salt mass pushed older formations to the surface, where they crop out, ringlike, around the center of the dome. As the water level in these ringlike outcrop areas is higher than that in water-bearing beds of the Wilcox group adjacent to the dome, it appears that water entering the ringlike outcrops has flushed salt water from the flanks of the dome and consequently generally increased the depth to which fresh water occurs in the area. Ground-water conditions at Rayburns dome indicate that the occurrence of fresh water probably is very erratic in the immediate vicinity of other intrusive salt masses and consequently exploration for ground water near similar

structures should be undertaken prior to development. The salt dome at Weeks Island is shown between wells 139 and 140 on plate 2.

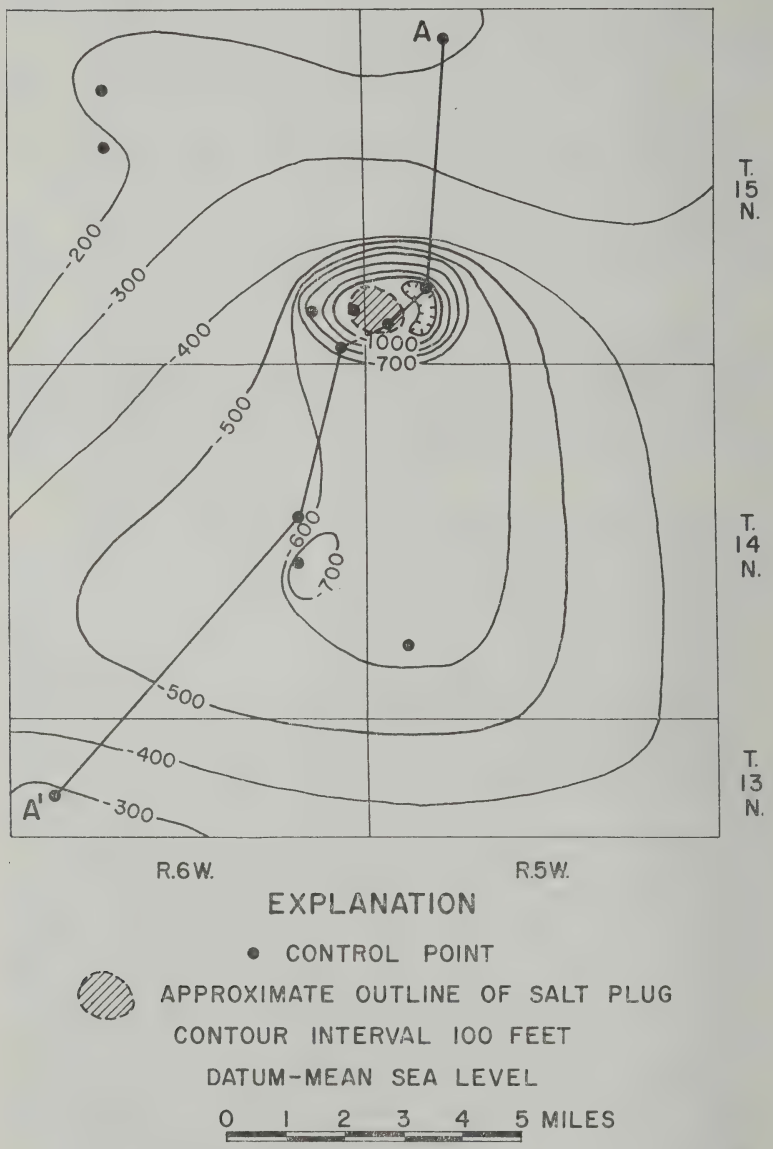

Figure 4. Map showing by contours the altitude of the base of fresh ground water in the vicinity of Rayburns salt dome, Bienville Parish.

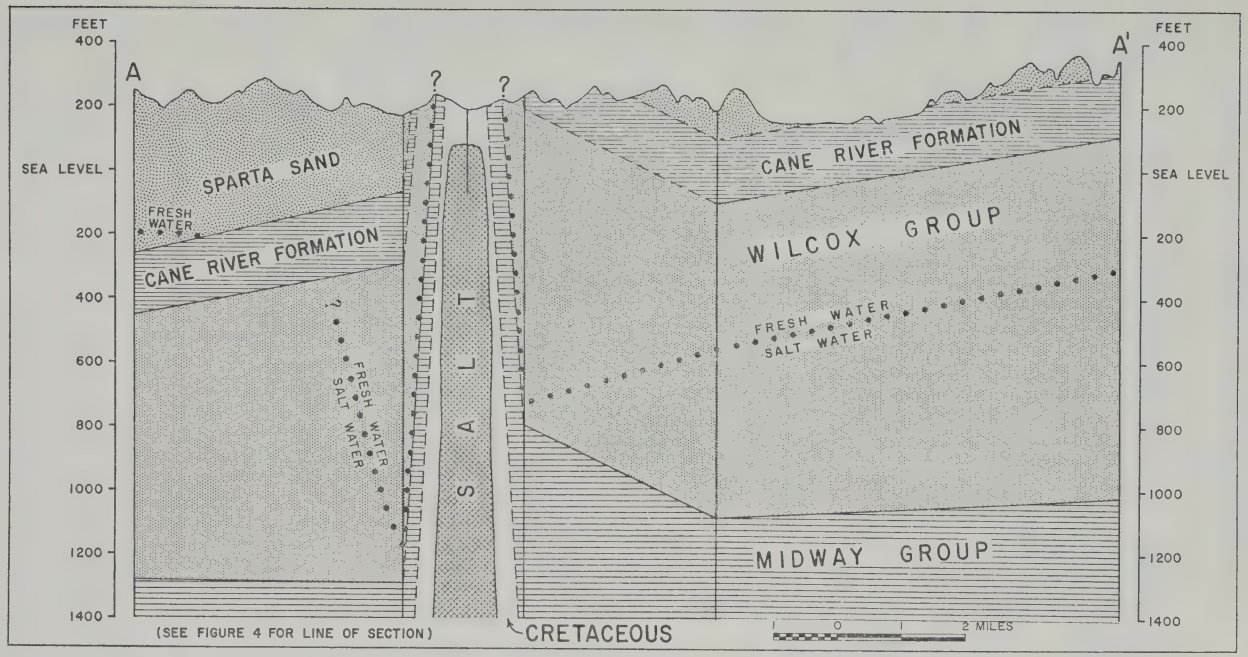

Figure 5. Geologic section of Rayburns salt dome, Bienville Parish.

PRINCIPLES OF OCCURRENCE OF GROUND WATER

Water-Table and Artesian Condition

Water is contained in a water-bearing unit or aquifer chiefly under one of two physical conditions—water-table or artesian. Under water-table conditions, water in an aquifer is unconfined by impermeable layers and is under atmospheric pressure. The aquifer functions much like a storage reservoir. Precipitation may enter the water-table aquifers directly in areas of outcrop, causing a rise in water level and a temporary increase in storage. The upper surface of the zone of saturation in a water-table aquifer is called the water table. This surface is not flat but undulates with the topography and with local conditions of addition or subtraction of water to the system.

Artesian aquifers are overlain and underlain by relatively impermeable beds and the contained water is under pressure. Water which enters an aquifer in its outcrop area flows slowly downward to the water table in response to gravity. Within the aquifer the water may flow beneath a confining bed and thus there is a conversion from water-table to artesian conditions. However, artesian aquifers need not crop out at the land surface as they may receive recharge by interaquifer movement of water. The water beneath a confining bed is under pressure, the head being equal to the weight of the vertical column of water which extends from the water table to the point at which the head is being measured, less the losses due to friction. Artesian wells do not flow necessarily; they flow only when the altitude of the land-surface is less than that of the piezometric surface. The piezometric surface is an imaginary surface that everywhere coincides with water levels in wells.

Recharge, Discharge, and Movement

Recharge is the addition of water to an aquifer. Rainfall is the principal source of recharge to the aquifers of Louisiana. Some aquifers are recharged by seepage from the beds of streams; most of the streams in the State, however, are fed by ground water. Differences in head

between aquifers may cause a slow interchange of water from one aquifer to another, but the total amount of ground water in storage is unaffected by the process.

Discharge is the loss of water from an aquifer. Ground water in an aquifer may be discharged by evapotranspiration, effluent seepage, interaquifer leakage, and pumping from wells. Natural discharge far exceeds the total discharge from wells in Louisiana.

Ground water moves in response to two principal factors, gravity and differences in head, and is retarded primarily by friction and molecular attraction. In a hydrologically balanced system the recharge is counterbalanced by an equal amount of discharge. Ground water moves generally in the direction of the regional dip of geologic formations in Louisiana; however, there are many local variations caused by pumping from wells and local structural and hydrologic anomalies.

QUALITY OF WATER

All natural waters contain dissolved mineral matter. Precipitation, even before it reaches the ground, dissolves gases and minor quantities of mineral matter from the atmosphere. After reaching the ground, it continues to dissolve minerals and undergoes various chemical reactions, which may or may not affect its potability. The following discussions of chemical properties and mineral constituents of ground water are not inclusive but summarize briefly the items that generally are of primary concern to water users in Louisiana.

Dissolved solids. The dissolved solids reported in chemical analyses are approximations of the total mineral matter in the waters analyzed. They are obtained by evaporation of measured volumes of water, drying the residues at a given temperature, and weighing the dried residues.

Hardness. Hardness is a property of water attributable chiefly to alkaline earths, principally calcium and magnesium. Hardness is an indication of the soap-consuming capacity of the water and, indirectly, an indicator of

the scale-forming tendency of the water when used in boilers. An arbitrary hardness classification of water is: less than 61 ppm (parts per million), soft; 61 to 120 ppm, moderately hard; 121 to 200 ppm, hard; and in excess of 200 ppm, very hard.

Iron and manganese. Iron and (or) manganese in water, even in small quantities, is objectionable because they cause yellowish-brown to reddish-brown or black stains on plumbing fixtures and laundry. A concentration of more than 0.3 ppm of these elements together or singly is considered excessive in drinking water or public water supplies.

Chloride. An increase in chloride content increases the salinity of water, and chloride in large concentrations makes the water unfit for most uses. The U.S. Public Health Service suggests a limit of 250 ppm of chloride for water to be used on interstate carriers.

Fluoride. Fluoride is a minor constituent of ground water; however, more than 1.5 ppm in water used by small children generally causes mottling of tooth enamel. Concentrations of about 1.0 ppm is considered beneficial by most dental authorities (Lohr and Love, 1954, p. 39).

Nitrate. Nitrate in water in excess of a few parts per million may indicate contamination by sewage or other organic matter. Studies indicate that nitrate in excess of about 44 ppm in drinking water may be a contributing factor or the cause of infant methemoglobinemia ("blue babies") (Waring, 1949).

pH. The pH of a water is determined by its hydrogen ion concentration and thus is a measure of the water's acidity or alkalinity. A neutral water has a pH of 7.0. Progressive values on the pH scale below 7.0 denote increasing acidity and progressive values above 7.0 denote increasing alkalinity.

GENERAL AVAILABILITY OF FRESH GROUND WATER

Fresh ground water is available in Louisiana from aquifers that range in age from Paleocene to Recent. The following sections discuss general geology, the availability

of fresh ground water by geologic unit, sources of recharge, and ground-water movement and show by chemical analyses the quality of ground water.

CRETACEOUS SYSTEM

Rocks of Cretaceous age probably underlie all of Louisiana. However, their presence has not been confirmed in the southern part of the state because the depth at which they can be expected to occur has not been reached in exploratory drilling. The only known exposures of rocks of Cretaceous age in Louisiana are those associated with salt domes in the northern part of the State. Cretaceous structure and stratigraphy are complex and are not discussed because rocks of Cretaceous age are not known to contain fresh ground water in Louisiana. Reports by drillers and individuals that the Nacatoch sand of late Cretaceous age contains fresh water have not been verified.

TERTIARY SYSTEM

Midway Group

The Midway group of Paleocene age (Durham and Smith, 1958) is composed of two formations, the Clayton and the Porters Creek clay. The lithologic similarity of these formations make it difficult and often impossible to accurately determine their contact on electrical logs; therefore, they have not been differentiated in this report. These formations consist primarily of calcareous, carbonaceous clay. The typical electrical logs of the Midway group (fig. 6) show a thickness of 550 and 650 feet. These are typical thicknesses for the area where the Midway group is shown on the fence diagram (pl. 2). As shown in figure 6, the Midway group has distinctive electrical properties and may be recognized easily on electrical logs. Thus, it serves as an important correlative marker.

The Midway group is highest structurally in northwestern Louisiana, where the Porters Creek clay crops out or is near the surface. The Midway group dips in all directions from this high, the Sabine uplift (pl. 2).

The Midway group is not known to yield water to wells

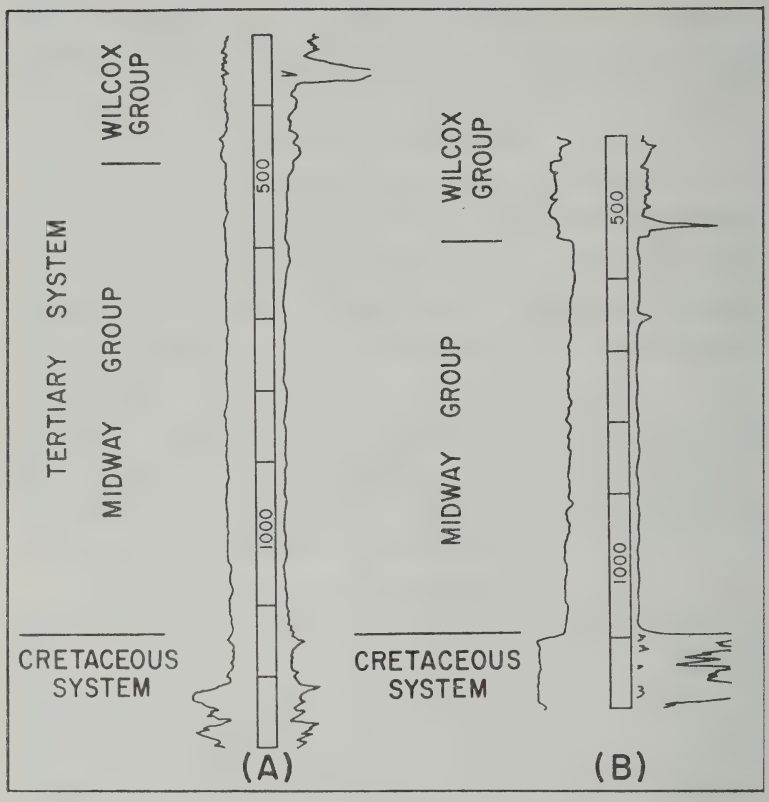

Figure 6. Typical electrical-log sections of the Midway group, (A) northwestern Louisiana and (B) north-central Louisiana.

in Louisiana. However, this group is important hydrologically as it inhibits vertical movement of ground water and underlies the oldest geologic unit (Wilcox group) containing fresh water in Louisiana.

Wilcox Group

The Wilcox group (Durham and Smith, 1958) includes those beds which lie stratigraphically above the Porters Creek clay of the Midway group and below the Cane River formation of the Claiborne group. Although this group has been separated into several formations by Murray (1948, 1955), it is undifferentiated in this report.

The Wilcox group is composed of a heterogeneous sequence of beds of lignitic sand, silty sand, sandy and silty clay, and clay. (See fig. 7.) These fine-grained deposits are continental to littoral in origin and lenticular. They form a deltaic sequence which thickens rapidly southward, a comparison of the logs on figure 7 gives an indication of this thickening. The group is about 350 feet thick in Union Parish, near the northern border of the State (fig. 7-B), whereas it is about 2,100 feet thick 70 to 75 miles south of this area, in central Winn Parish (fig. 7-C). This downdip thickening also is illustrated by the fence diagram (pl. 2).

Sands of the Wilcox group constitute the oldest geologic unit in Louisiana which is known to contain fresh ground water. Fresh ground water in Wilcox strata is limited to northwestern Louisiana, as shown in figure 8.

The fence diagram (pl. 2) illustrates the structural high in northwestern Louisiana and the attendant exposure of the Wilcox group. Rainfall is the principal source of recharge in the outcrop area. Additional recharge may take place by the movement of water through the beds of clay that overlie the Wilcox group; however, the amount of recharge from this source probably is very small compared to that supplied by rainfall in the outcrop area. Owing to the fact that the hydrostatic head of the Wilcox group generally is greater than that of the overlying Quaternary alluvium in the major steam valleys, water moves upward from the Wilcox into these deposits. This upward movement of water from the Wilcox into the alluvium in the Red River Valley is the principal means of discharge from sands of the Wilcox group in Red River Parish (Newcome, 1957, p. 58). Additional discharge takes place from wells, springs, and seeps.

Locally there may be areas where the water-bearing sands have been contaminated by, (1) movement of salt water in the vicinity of faults, (2) leakage from improperly plugged oil wells, (3) downward movement of wastes in areas of surface disposal, and (4) movement of salt water through confining beds of clay.

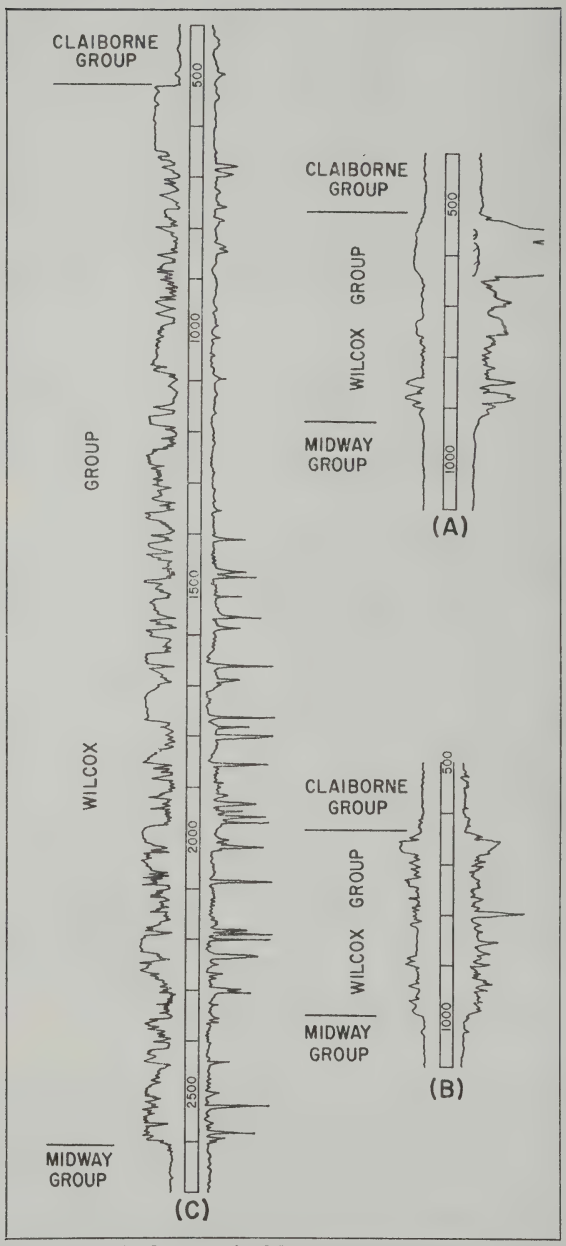

Figure 7. Typical electrical-log sections of the Wilcox group, (A) Caddo Parish, (B) Union Parish, and (C) Winn Parish.

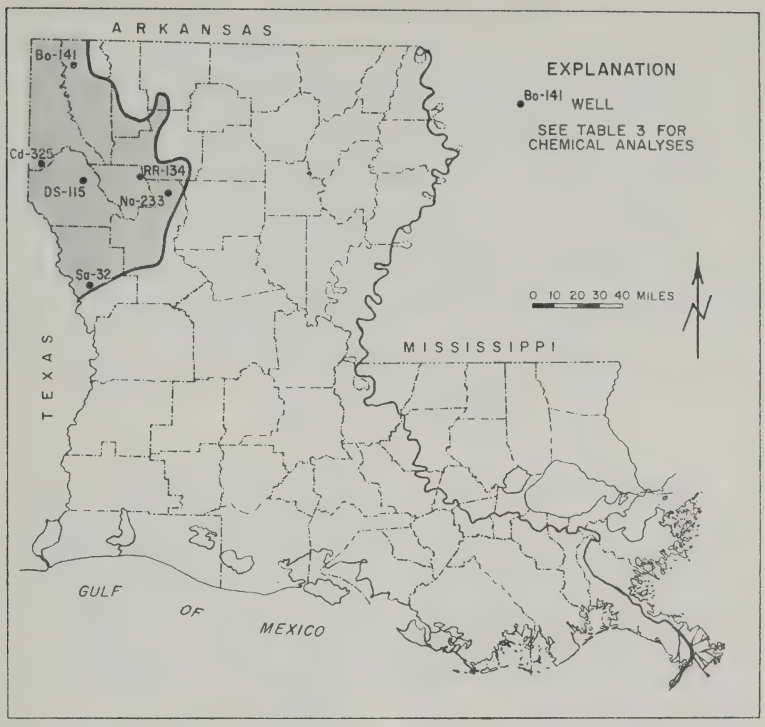

Figure 8. Map showing the approximate area where rocks of the Wilcox group contain fresh water.

Yields of wells completed in sands of the Wilcox group generally are small, ranging from a few gallons per hour from small-diameter domestic wells to approximately 500 gpm (gallons per minute) from some large industrial and public-supply wells. Relatively small yields are the general rule, owing to the fine-grained texture and lenticularity of the water-bearing sands.

The quality of water in these deposits is variable. The analyses of water from six representative wells at various localities within the fresh-water region shown in figure 8 are listed in table 3. In the outcrop areas in Bossier and Caddo Parishes some wells (Bo-141 and Cd-325 in fig. 8) yield soft to moderately hard acid-tending water of low mineral content. Water from wells in these outcrop areas generally must be treated for the removal of iron. In Red River Parish, where these sands receive local

recharge, the water is a basic-tending, moderately hard, calcium bicarbonate type, and contains an excessive amount of iron. In DeSoto, Natchitoches, and Sabine Parishes, downdip from the outcrop areas the water becomes more mineralized, having higher concentrations of sodium, bicarbonate, and dissolved solids. Locally the concentration of certain constituents may vary radically; for example, the water from well Na-233 has high concentrations of sulfate and iron, whereas, the water from well Sa-32 in Sabine Parish has an extremely low content of sulfate and a low iron content. There are also considerable variations in the concentrations of bicarbonate, chloride, and fluoride.

Claiborne Group

The Claiborne group of Eocene age comprises, in ascending order, the Cane River, Sparta, Cook Mountain, and Cockfield formations. Two of these formations, the Cane River and the Cook Mountain, are only minor sources of fresh water because they are composed primarily of clay; the Sparta and Cockfield formations, however, are important sources of fresh ground water in northern Louisiana.

Formational contacts in the Claiborne group can be determined from electrical logs (fig. 9), at least to the depths shown on the fence diagram (pl. 2). However, these contacts are gradational in some places and there may be minor discrepancies between electrical-log and paleontological determinations.

CANE RIVER FORMATION

Martin (1954, p. 77) described the Cane River formation in Webster Parish as being " . . . marine, gray-green, glauconitic sandy silt and shale overlain by chocolate-brown silty shale." At the type locality, south of the area where Martin described this formation, the lower part of the Cane River is calcareous and contains abundant microfauna. This description is more or less typical of the Cane River formation, except in extreme northwestern Louisiana where this sequence contains interfingering sands. (See Smith, 1958.) The formation ranges in thick-

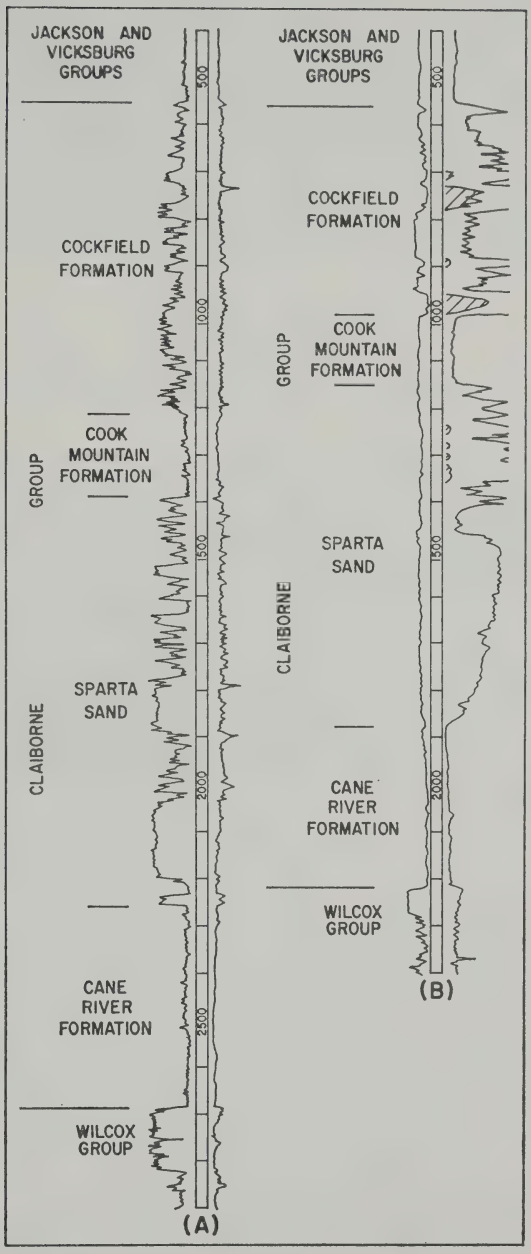

Figure 9. Typical electrical-log sections of the Claiborne group, (A) central Louisiana and (B) northeastern Louisiana.

ness from about 250 feet updip to 500 feet downdip. (See pl. 2 and fig. 9.) Except in extreme northwestern Louisiana this formation is restricted to the shale section immediately above the Wilcox group and is easily discernible on electrical logs (fig. 9). In northern Caddo and Bossier Parishes the interfingering sands contain fresh water. As there has been no known development of this potential source, chemical analyses of its water are not available. This lack of development is due to the large quantities of fresh water available from the overlying Sparta sand.

SPARTA SAND

Spooner (1926, p. 236) described the Sparta sand in the following manner:

> . . . The lower half of the Sparta sand is made up chiefly of massive sand with interbedded subordinate members of laminated sandy clay. The massive sands are made up of quartz grains somewhat coarser than found in the Wilcox formation. The upper half contains a relatively greater amount of clay than the lower half. Massive sands alternate with beds of finely laminated sandy clay, in part lignitic and in many places containing fossil leaves. The upper 50 feet of beds contain a considerable amount of lignitic material and some thin lignitic beds which are particularly well exposed in the vicinity of the town of Bienville. The beds are commonly light colored, but, depending upon the amount of iron and carbonaceous matter, red- and brown-colored beds occur. Fossils are generally absent from the Sparta sand, but a few species of near-shore forms are found near the middle of the formation.

The Sparta sand ranges in thickness from about 500 to 900 feet in the area where it contains fresh water. The electrical-log sections in figure 9 show that the lithology of the formation is similar to that described by Spooner; the massive beds of sand near the base and the relatively greater content of clay in the upper part of the formation.

The Sparta sand in southern Louisiana is more clayey and difficult to distinguish from the overlying Cook Mountain and underlying Cane River formations on electrical logs.

The areal distribution of fresh water in the Sparta sand is shown in figure 10. The Sparta sand contains fresh water in three places; namely, (1) a narrow belt in

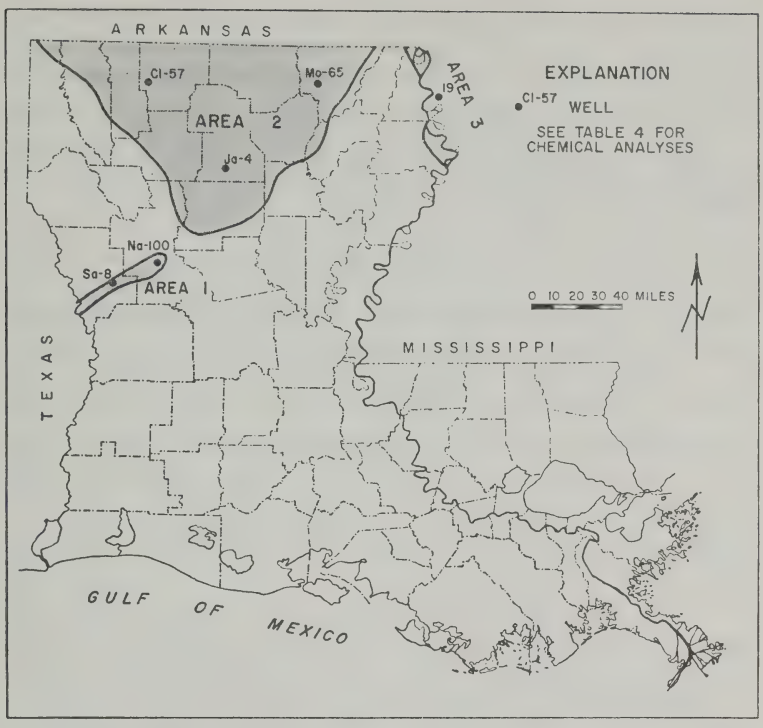

Figure 10. Map showing the approximate areas where rocks of the Sparta sand of the Claiborne group contain fresh water.

Sabine and Natchitoches Parishes, (2) a broad area encompassing most of north-central Louisiana, and (3) two small areas in the northeastern corner of the State immediately adjacent to the Mississippi River.

Area 1 corresponds roughly to the outcrop of the Sparta sand west of the Red River Valley. The source of recharge in this area probably is confined to rainfall. Few wells are completed in the Sparta sand in this area and natural discharge probably greatly exceeds artificial discharge. The principal areas of natural discharge probably are into the alluvium in the Sabine and Red River valleys. Movement would therefore be from the Sparta highlands northeastward and southwestward toward these valleys.

The quantity of water pumped from the Sparta sand in area 1 is small. No wells are known to yield more than

365 gpm, and most wells yield from a few gallons per hour to about 40 gpm. The water-bearing sands of the Sparta throughout most of the area are relatively thin and would not economically yield large quantities of water to wells. The sands are thicker near the eastern edge of the area, however, and properly constructed large-diameter wells might yield as much as 1,000 gpm.

Analyses of water from two wells, Na-100 and Sa-8, are included in table 4 and indicate the quality of water available from the Sparta sand in area 1. These analyses show the water is a soft sodium bicarbonate type that is low in chloride but relatively high in total iron. An increase in sodium bicarbonate content with depth indicates a natural softening by base exchange, which would tend to make the water more desirable for some purposes even though there is an increase in dissolved solids. The undesirable concentrations of iron could be reduced by treatment.

Area 2 on figure 10 represents the approximate areal extent of the most important aquifer in northern Louisiana. Jones and Holmes (1947, p. 31, 32) described the recharge of the Sparta sand as follows:

> . . . Water from precipitation and stream flow enters sand beds of the Spartar where they crop out to the west, northwest, and southwest of the Monroe area. The sands are exposed to recharge from precipitation . . . throughout much of the upland area of northern Louisiana . . . Basal sands of the Sparta, which is relatively flat lying throughout the area between Minden and Monroe, are recharged where they have been pushed sharply upward and exposed by erosion on local salt-dome structures . . . Sands in the upper or middle part of the formation are doubtless exposed to recharge throughout much of the upland area of northern Louisiana where deeply incised drainageways, such as that of Bayou D'Arbonne, cut into it. The interconnection of most sand bodies in the middle and lower parts of the formation effectively shortens the distance from the outcrop, or area of recharge, to points of withdrawal from the basal sands of the formation.

Although the preceeding statements were made in discussing recharge as it affected the Sparta sand in the Monroe area, they also describe representative recharge conditions for area 2. The movement of ground water in the geologic past probably has been downdip principally toward the axes of the Mississippi structural trough and the Gulf

Coast geosyncline. However, in recent times this ancestral pattern of movement has been altered locally by heavy pumping of ground water for industry and public supply.

Few data are available for evaluating the quantity of discharge from the Sparta sand in northern Louisiana, but the quantity of natural discharge probably exceeds that of artificial discharge. Natural discharge is limited primarily to movement of water from the Sparta sand through the overlying and underlying confining beds. In areas of heavy pumping, water may be moving through the confining clays into the Sparta sand because of the artificially induced difference in head. Areas of heavy withdrawals from the Sparta sand and the accompanying decline of water levels are discussed in the section, "Summary of ground-water availability."

Yields of wells in area 2 range from a few gallons per minute from small domestic wells to more than 2,000 gpm from some large-diameter industrial wells that tap thick beds of sand in the lower part of the Sparta sand.

Analyses of water from three representative wells screened in the Sparta sand in area 2 are included in table 4. Quality-of-water data indicate that water from the Sparta generally is soft, of the sodium bicarbonate type, and, except for some small areas, low in iron. The water from well Cl-57, in the outcrop area in Claiborne Parish, has a low mineral content but is acid tending and has an iron content in excess of 0.3 ppm. The water from well Ja-4 in Jackson Parish, southward and downdip from the outcrop area, is more mineralized, having higher concentrations of sodium and bicarbonate. Water from well Ja-4 contains less iron than that from well Cl-57, however, and is softer as a result of base exchange which took place as the water migrated slowly downdip. Water from well Mo-65 in Morehouse Parish, farther downdip from the outcrop area, is soft, basic tending, and has low iron content but is more mineralized than water from wells Cl-57 and Ja-4. The chemical constituents which increased markedly are sodium, bicarbonate, and chloride. The increase in chloride content probably is the result of westward movement of salt water toward the area of heavy

industrial withdrawals in the vicinity of Mo-65. The Sparta sand contains salt water east of Mo-65, along the east boundary of Morehouse Parish, in West Carroll Parish, and in most of East Carroll Parish.

There are no known water wells in the Sparta sand in area 3 on figure 10 and the area of fresh ground water was mapped on the strength of electrical-log data. An analysis of water from well 19 in Issaquena County, Miss. (about 15 miles southeast of Lake Providence, La.) is included in table 4 and probably is indicative of the quality of water in the Sparta sand in area 3.

COOK MOUTAIN FORMATION

The Cook Mountain formation is composed of fossiliferous marine clay, marl, and glauconitic sand. In the area where it appears on the fence diagram (pl. 2) the Cook Mountain formation ranges in thickness from about 100 feet, in northeastern Louisiana, to about 300 feet in central Louisiana, where it dips to the southeast toward the axes of the Mississippi structural trough and the Gulf Coast geosyncline. This clayey formation generally can be distinguished on electrical logs from the overlying predominantly sandy Cockfield formation and underlying Sparta sand (fig. 9).

Sand lenses in the Cook Mountain formation yield fresh water to wells only in the areas of outcrop. The maximum known yield from a well in these deposits is 50 gpm; large yields cannot be expected owing to the fine-grained texture and the lenticularity of the water-bearing sands.

COCKFIELD FORMATION

The Cockfield formation consists of beds of lignitic sand, silt, and clay of continental to littoral origin. The sands generally are very fine to fine grained and individual beds may be 100 feet or slightly more in thickness. In general the thicker sand beds are in the lower part of the formation. The electrical logs in figure 9 show that these thick sand beds may contain thin layers of clay or sandy clay. The total thickness of the Cockfield formation increases from about 450 feet near the outcrop area to about

1,000 feet near the southern limit of its appearance on the fence diagram (pl. 2).

The Cockfield formation is shown on electrical logs as the predominantly sandy sequence between the Cook Mountain formation and the Jackson and Vicksburg groups (fig. 9). Its contact with these units generally is sharply defined. The contact with the underlying Cook Mountain formation is picked on electrical logs at the boundary of the top of the typical clay of the Cook Mountain. Although this contact is satisfactory for mapping, the age boundary may differ slightly from the lithologic boundary, as the sediments of the upper Cook Mountain are reported to be gradational with those of the lower Cockfield formation (Martin and others, 1954, p. 95). Except at considerable depth, where the equivalent sediments are lithologically similar to the Cook Mountain, it is relatively easy to delineate the Cockfield formation on electrical logs.

Fresh ground water occurs in the Cockfield formation in two areas that are separated by the Red River Valley. The areal distribution of fresh water in the Cockfield formation is shown on figure 11. Area 1 is a narrow belt in Sabine, Natchitoches, and Vernon Parishes, and area 2 is a broad region which includes much of northeastern Louisiana.

The relation of recharge and discharge in area 1 is similar to that of the Sparta sand. (See area 1 in fig. 10.) Owing to the relatively steep southward dip of the formation, recharge from precipitation has flushed salt water from the water-bearing sands only a short distance downdip from the outcrop area. As in the Sparta sand, water moves downdip from the highlands and laterally toward the adjacent valleys of the Sabine and Red Rivers. The depth to which flushing has been effective is greater in the Cockfield formation than in the Sparta sand. Fresh ground water occurs at depths of more than 2,000 feet below sea level in the Cockfield and only slightly more than 500 feet in the Sparta sand.

The largest known discharge from a well in the Cockfield formation in area 1 is about 100 gpm. The hydraulic characteristics of the formation indicate, however, that

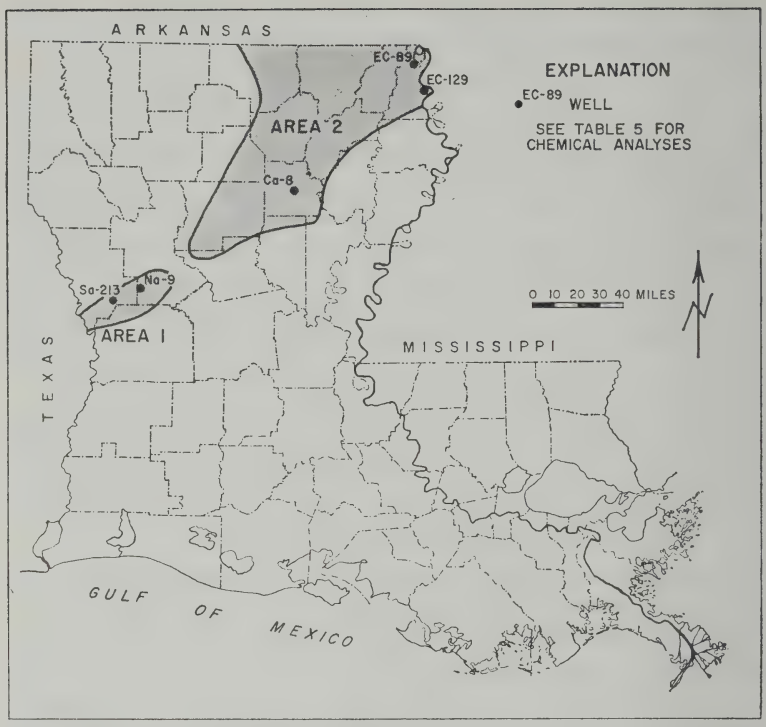

Figure 11. Map showing the approximate areas where rocks of the Cockfield formation of the Claiborne group contain fresh water.

larger yields can be obtained from properly constructed and developed wells. The deepest well in the Cockfield in area 1 is 1,300 feet, consequently, the only data available on the deeper fresh water in the formation have been interpreted from electrical logs of oil-test wells.

Two analyses of water from the Cockfield formation in area 1 are included in table 5. As shown by these analyses, the water ranges from soft to moderately hard, and the chloride content is low. The water from well Sa-213, near the outcrop area, had a high total iron content. As the water migrates downdip, the water is softened naturally by base exchange. This is indicated by the low hardness and greatly increased sodium bicarbonate content of water from well Na-9.

The Cockfield formation in area 2 (fig. 11) is a source

of fresh ground water in a large part of northeastern Louisiana. Outliers of the Cockfield in many places on the western edge of area 2 contain ground water, probably under water-table conditions. To the east water-table conditions exist where the aquifer is exposed on the surface; but, in the subsurface, artesian conditions exist as clay beds from effective confining layers. In northeastern Louisiana water in the alluvium of the Mississippi River valley recharges the underlying aquifers of the Cockfield formation. The hydraulic gradient between the alluvium and the Cockfield is reversed farther south, and water moves from the Cockfield into the alluvium. This condition exists southward to the area where the clay of the Jackson group overlies the Cockfield formation. This clay barrier between the alluvium and the Cockfield formation prevents the flushing of the aquifers in the Cockfield south of the line where Jackson sediments underlie the alluvium.

The Cockfield formation in north-central Louisiana is recharged principally from rainfall, and ground water in the formation moves generally downdip toward the axis of the Mississippi structural trough.

The maximum known yield of a well in the Cockfield formation in area 2 is about 700 gpm. Few large-capacity wells have been installed because more prolific sources of supply are generally available from the Sparta sand or the Quaternary alluvium. However, in areas where the Cockfield formation is overlain by the alluvium public-supply wells generally are drilled to the Cockfield to obtain water of a better quality.

Water from the Cockfield formation ranges from soft to very hard and is low in chloride; locally the iron content may be excessive. Water from some wells has a yellowish color which is due to organic matter. This color is most common in waters from the uppermost part of the formation but its occurrence at a given locality cannot be predicted. Analyses of water from three wells in area 2 indicate the quality of ground water in the Cockfield formation. (See table 5.)

Jackson and Vicksburg Groups

The Jackson group of Eocene age and the Vicksburg group of Oligocene age are lithologically similar where they are shown on the fence diagram (pl. 2). They consist of carbonaceous shale, sandy clay, and marl. Although these two groups cannot be differentiated by their electrical properties (fig. 12), they can by paleontological

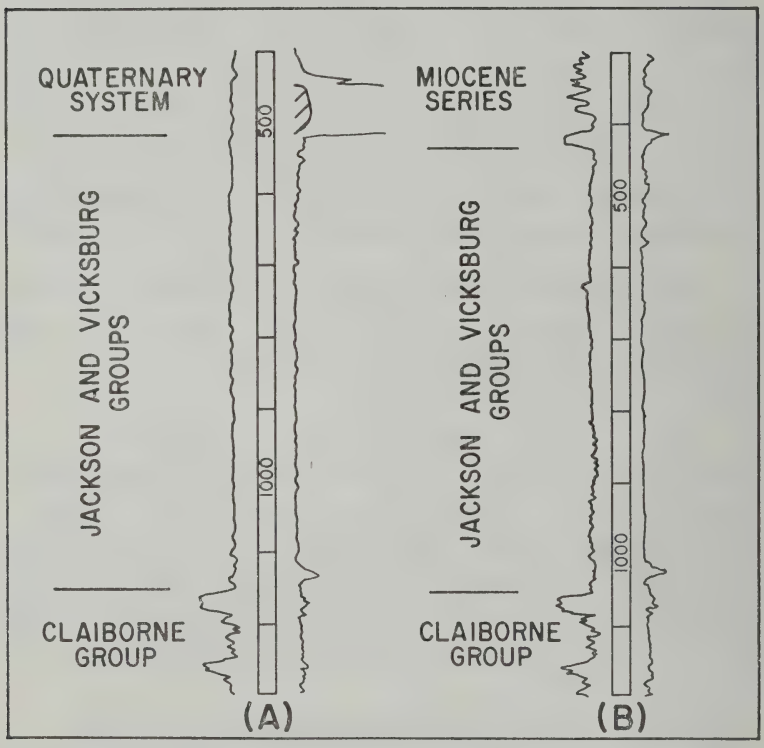

Figure 12. Typical electrical-log sections of the Jackson and Vicksburg groups, (A) where overlain by alluvial deposits and (B) as normally overlain by Miocene sediments.

data. They are considered as a unit in this report. Jackson-Vicksburg sediments in north-central Louisiana crop out in a narrow belt trending northeast and dip to the southeast. The full thickness of the two units ranges from about 300 to 900 feet (pl. 2).

The Jackson and Vicksburg groups are of little importance as aquifers. In the outcrop area, lenses of silt and fine-grained sand yield small quantities of water to wells. The Vicksburg group in northeastern Washington Parish is reported to consist predominantly of limestone which electrical logs indicate may contain brackish water. No wells in Louisiana are known to tap these beds, and consequently there is no information about the quality of the water except that inferred from electrical logs.

Miocene Series

The deposits stratigraphically above the Vicksburg group of Oligocene age and having an upper limit defined by the brackish water clam *Rangia johnsoni* are considered to be of Miocene age. These deltaic deposits form a great gulfward-thickening wedge. Their greatest thickness is not known, but an oil-test well near the mouth of the Mississippi River was still in Miocene strata at a total depth of 22,559 feet.

Miocene deposits consist of interfingering lenticular beds of fine- to medium-grained sand, silt, and clay. The deposits are continental to littoral updip and marine downdip. They contain beds of bentonite and bentonitic clay, plant impressions, and lignite in some areas.

The lenticularity of these deposits prevents subdivision by electrical-log data (fig. 13), necessitating the use of paleontological data for long-range correlations. Consequently the Miocene sediments are considered as a unit in this report.

Fresh water occurs in sediments of Miocene age in a broad eastwest trending belt which extends across the south-central part of Louisiana (fig. 14). Although this belt is continuous, it is almost severed in the central part of the area by a zone containing salt water which extends northward parallel to the axis of the Mississippi structural trough. Although there may be several factors that caused this salt-water zone, it probably represents an area that has not been flushed completely by fresh water moving

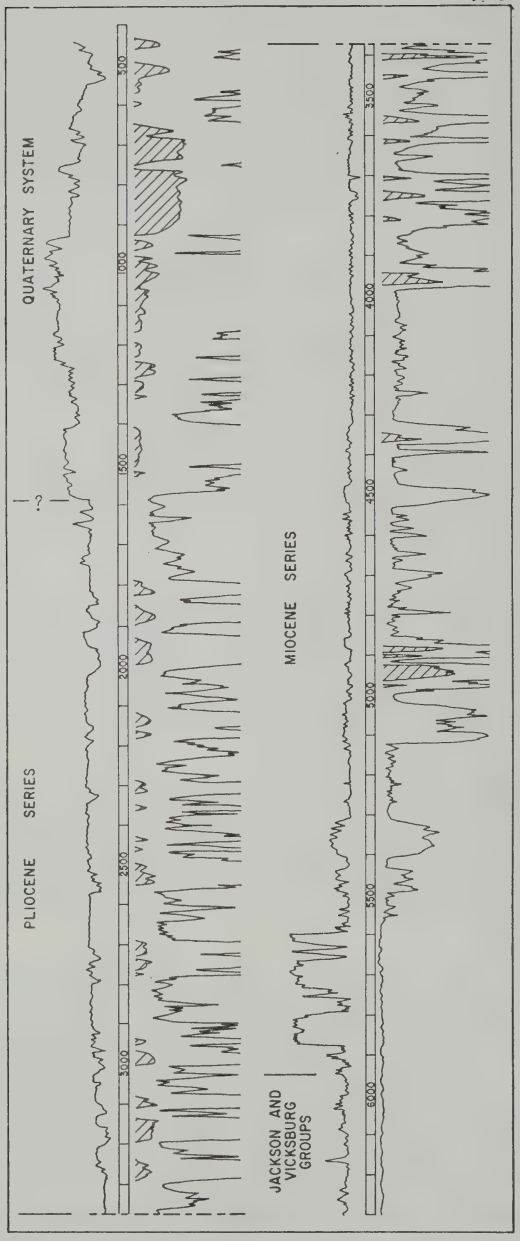

Figure 13. Composite electrical log section of Miocene, Pliocene, and Quaternary deposits.

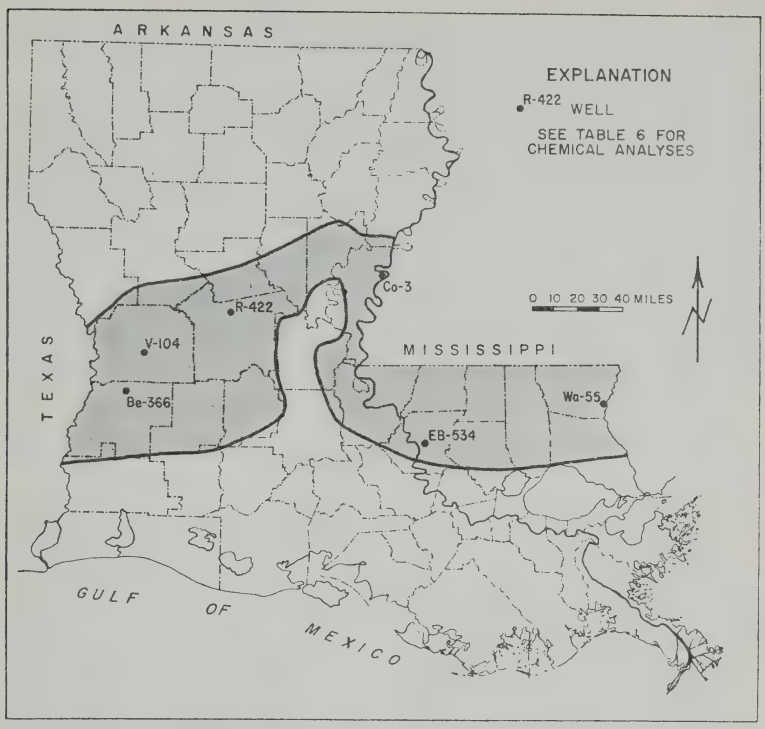

Figure 14. Map showing the approximate area where rocks of the Miocene series contain fresh water.

within the Miocene aquifers from the highlands on both sides of the valley.

The rather abrupt southern limit of fresh water in the Miocene deposits is the extent to which flushing of the aquifer has proceeded downdip. The front may be in equilibrium or advancing slowly southward.

Wells screened in sands of the Miocene series in the eastern part of the area (fig. 14) yield as much as 2,000 gpm. These sands have not been developed extensively in the western part of the area, and the largest reported yield from a well is 1,000 gpm. Generally, wells in the eastern part of the area flow, but those in the western part do not.

Analyses of water from several representative wells completed in fresh-water-bearing sands of Miocene age are

listed in table 6. These analyses indicate that the water normally is suitable for most purposes without treatment. The water generally is of the very soft, sodium bicarbonate type and contains small amounts of iron. The water from well Co-3 in Concordia Parish is more mineralized than that from Miocene sands farther south and is highly colored. This color, which probably is caused by organic matter, makes the water undesirable for human consumption. Water from well R-422 contains an objectionable amount of fluoride—enough to cause mottling of the tooth enamel of children. Fluoride in ground water in Avoyelles and Rapides Parishes was treated in detail by Maher (1939).

Pliocene Series

Deposits of Pliocene age probably do not crop out in Louisiana. However, a thick section of sediments overlying the *Rangia johnsoni* zone and underlying the base of the last gravelly sequence of the Pleistocene series was assigned to the Pliocene in southwestern Louisiana by Jones (1954, p. 56-61). Jones' age assignment was restricted to southwestern Louisiana, where he named one formation (Foley) and divided it into two members (Mamou and Steep Gully). This sequence is a series of beds of medium- to fine-grained lenticular, deltaic sand, clay, and silt which are lignitic, slightly calcareous, and locally contain much marcasite and pyrite. The Pliocene and overlying Pleistocene deposits east of the Mississippi River are difficult to distinguish because of their lithologic similarity. The Pliocene was not recognized by Meyer and Turcan (1955, p. 10) in the Baton Rouge area, and they assigned the entire sequence of sediments overlying the Miocene to the Pleistocene. This assignment was based upon the dissimilarity of these nonlignitic sediments with those in southwestern Louisiana described by Jones. However, by extending the basal Pleistocene deposits of southwestern Louisiana eastward across the Mississippi alluvial valley a tentative correlation is made with the "600-foot" sand of the Baton Rouge area (Meyer and Turcan, 1955, p. 27). This correlation may be extended eastward to the Pearl River on the basis of electrical logs and, in some places,

basal gravel. This tentative correlation of the upper Pliocene contact is shown on the fence diagram (pl. 2).

The areas where deposits of Pliocene age contain fresh water are outlined on figure 15. Pliocene deposits contain fresh water in a broad belt across south-central Louisiana. This belt is divided into two distinct areas by a zone through St. Landry Parish in which Pliocene deposits contain no fresh water. The position of this central salt-water zone corresponds closely to a similar zone in the Miocene. (See fig. 14.) The lack of fresh water in the Pliocene and Miocene sediments in this region probably is caused by the same factors; that is, fresh water entering the recharge areas in the highlands on both sides of the Mississippi alluvial valley has not yet flushed the salt water from the Pliocene and Miocene deposits that underlie the alluvium because of a tendency to discharge into

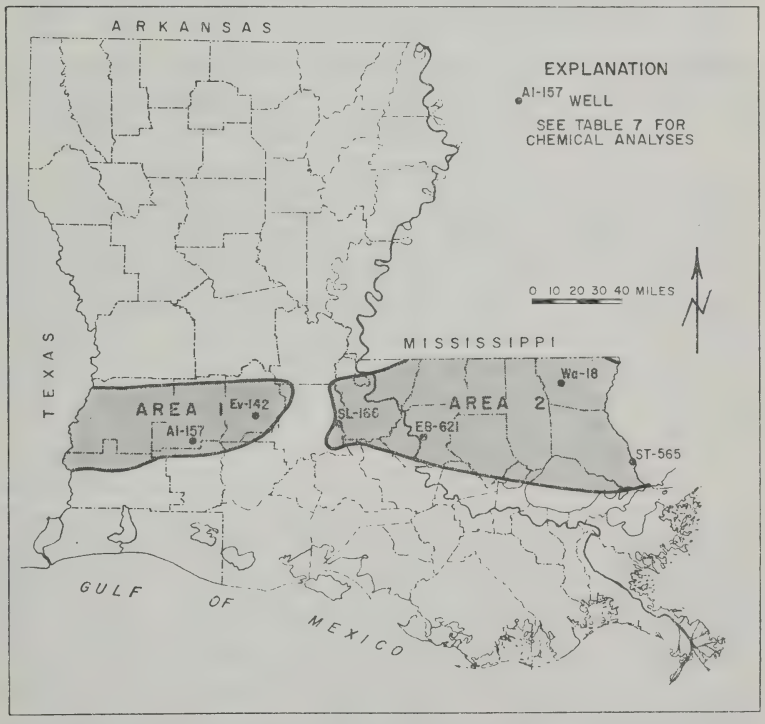

Figure 15. Map showing the approximate areas where rocks of the Pliocene series contain fresh water.

the alluvium on the fringes of the valley. The sharp decrease in the depth of fresh water occurrence (pl. 3) marks the southern limit of flushing by fresh water in Pliocene deposits.

Yields of wells in the deposits of Pliocene age generally are less than those from the overlying Quaternary deposits. The largest known yield from Pliocene deposits in area 1 is about 1,000 gpm from a well at Oakdale, in Allen Parish. Only a few wells have been completed in strata of Pliocene age in area 1 mainly because of the availability of large quantities of water from the overlying Quaternary deposits. The primary reason for the development of this aquifer is to obtain water of a better quality than that from the overlying Quaternary deposits. Two analyses of water from the Pliocene in area 1 are included in table 7. These analyses indicate that the water is of the soft sodium bicarbonate type, but, both samples were greatly discolored, probably due to organic matter, and had a somewhat high total iron content. In addition, water from well Ev-142 contains fluoride in a concentration high enough to cause severe mottling of the teeth of children.

In area 2 many wells are completed in Pliocene deposits to take advantage of the good quality of water and high artesian head. Flowing wells are common throughout this area except in the Baton Rouge area where large withdrawals of water for municipal and industrial supplies have lowered the piezometric surface. The largest yield from the Pliocene sediments in area 2 is a natural flow of about 3,200 gpm from a municipal-supply well at Slidell.

Analyses of water from four wells in area 2 are listed in table 7. These analyses indicate that the water typically is the soft, sodium bicarbonate type. Other chemical constituents vary in concentration areally and with depth. Shallower wells generally yield acid-tending waters with lower dissolved-solids content and greater quantities of iron than water from the deeper wells. Three of the samples of water from area 2 were slightly discolored. This color would not be readily apparent, but one well (SL-166)

yields water which has a color higher than the limit of 20 set by the U.S. Public Health Service.

QUATERNARY SYSTEM

The Quaternary deposits of Louisiana are composed of sediments of Pleistocene and Recent age. The Pleistocene deposits are of two general types; an approximately coastwise, gulfward-thickening wedge of deltaic sediments and the relatively thin, veneerlike deposits which form the stream terraces and alluvial valley fills. The deposits of Recent age form a thin mantle of sand, silt, and clay restricted to stream valleys and coastal areas. The Recent deposits generally are thin and not important as aquifers; therefore, they are not differentiated from the deposits of Pleistocene age on plate 2. The deposits of Pleistocene age that have been divided into formations by Fisk (1938, 1940, and 1944) and Jones (1954) comprise several hydrologic units which do not coincide with the formations.

It is difficult to differentiate between the coastwise Quaternary deposits and the underlying Pliocene deposits in those areas where the basal Quaternary deposits are not gravelly. The lack of distinctive lithologic units at the contact of Pliocene and Quaternary deposits is illustrated by the composite electrical log of the Miocene, Pliocene, and Quaternary deposits (fig. 13). Thus, correlations must be considered approximate because of the lithologic similarity of the two deposits. The Quaternary deposits throughout the State are composed of gravel, sand, silt, and clay and range in thickness from less than 50 feet in central and northern Louisiana to more than 3,500 feet near the coast. They are shown as one unit on the fence diagram (pl. 2).

The Quaternary deposits, which blanket most of Louisiana (pl. 1 and fig. 16), yield about two-thirds of all the ground water pumped in the State. To describe the availability of fresh water the Quaternary deposits have been divided into upland and valley deposits. The relatively thin Quaternary valley deposits fill the major stream valleys and blanket the coastal areas. The Quaternary upland deposits also consist of two major groups—the rela-

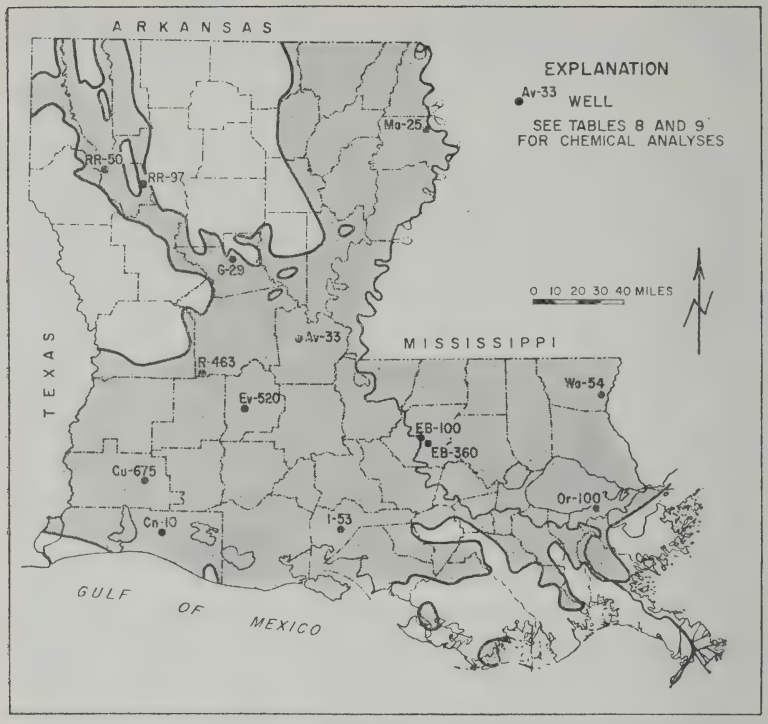

Figure 16. Map showing the approximate area where rocks of the Quaternary system contain fresh water.

tively thin terraced deposits which flank the stream valleys of northern Louisiana and the coastwise terraced deposits which dip and thicken toward the coast. (See pl. 2.)

Quaternary Valley Deposits

The Quaternary valley deposits are recharged mainly from rainfall. The streams that flow across these deposits normally are effluent during most of the year, and groundwater discharge contributes significantly to the base flow of these streams. The hydraulic gradient near the streams is reversed during high-water stages, and the streams become influent for brief periods. However, on a yearly basis the discharge into streams exceeds the recharge from them. The valley deposits are recharged to a small extent from upward movement of water from underlying aquifers of Tertiary age and from lateral movement from adjacent

Quaternary upland deposits. Movement of ground water in the valley deposits is generally toward the major streams and downstream, because of the gradient imposed by topography.

The occurrence of fresh ground water is irregular in the lower Mississippi River valley. (See fig. 16—east of well I-53 and south of well Or-100.) The occurrence of fresh ground water in this area may be related to the positions of ancestral channels of the Mississippi River.

Valley deposits throughout much of the State are composed of sand and gravel near the base and become progressively finer grained toward the top. The basal sand and gravel is a prolific source of water and wells in the deposits yield as much as 4,000 gpm.

Analyses of water from five wells completed in Quaternary valley deposits are given in table 8. These analyses show that the water generally is very hard and has a high total iron content. The hardness ranges from 228 ppm to 480 ppm. All the analyses listed in table 8 show a total iron content in excess of the U.S. Public Health Service's recommended limit of 0.3 ppm. However, the potentially high yields of wells in these deposits and the relatively low water temperature make these deposits an excellent source of water for irrigation and some industrial purposes.

Quaternary Upland Deposits

Terraced deposits of northern Louisiana

The terraced deposits which flank the stream valleys and cap the older formations in northern Louisiana are recharged by local rainfall. Ground water in these deposits generally is under water-table conditions and moves from topographically high positions to local stream valleys.

The terraced deposits generally are composed of a sedimentary sequence which ranges in grain size from coarse at the base to fine at the top, much like the deposits in the valley areas. The lower part of the section in many areas contains gravel, but the yields of wells completed in these deposits, generally are small because of the relatively thin saturated thickness of the deposits.

The analyses of water from two wells (G-29 and RR-97) completed in these deposits are given in table 9, and the locations of the wells are shown on figure 16. Water from these deposits has a very low dissolved-solids content and is soft. Excessive total iron concentrations (greater than 0.3 ppm) would require some treatment to make the water completely suitable for domestic use.

COASTWISE TERRACES AND THEIR SUBSURFACE EQUIVALENTS

The terraced deposits of northern Louisiana coalesce with their coastwise equivalent in the southern third of the State. The coastwise deposits gradually dip and thicken gulfward. These sediments have been named the Chicot reservoir in southwestern Louisiana (Jones, 1954, p. 138). The equivalent but finer textured sequence in southeastern Louisiana is unnamed.

The deposits are recharged mainly by rainfall in the outcrop areas throughout southern Louisiana. In southwestern Louisiana, because of heavy withdrawals there are several additional sources of recharge. These sources of recharge are from water moving through the confining beds (Jones, 1954, p. 170-172) and perennially or periodically from streams that incise the aquifers. Such recharge is undesirable where the water in the streams is salty, such as in the lower Vermilion River (Jones, 1954, p. 164-170). The hydraulic gradient in southwestern Louisiana in the recent past has been toward the Gulf of Mexico; however, heavy withdrawals for irrigation and industry have reversed the gradient along the coast and caused saline waters to move slowly northward. This movement is discussed by Jones (1954, p. 223-225), Fader (1957, p. 21), and Harder (1957, p. 158-160).

The coastal terrace deposits in southeastern Louisiana are a part of a larger hydraulic system. The distribution of head with depth in aquifers in the northern part of the area indicates that water from precipitation enters the terraced deposits, either in the outcrop area or through beds that are only partly confining, and migrates downward through the deposits and into the underlying aquifers. The land surface is underlain by clay in the southern part of

the area; however, some water from precipitation may migrate through this confining bed into the coastal terraced deposits. Deeper aquifers, which contain water under greater hydrostatic head, probably are additional sources of recharge.

Yields of wells completed in these deposits generally are large. The largest yield is about 6,000 gpm from a well for rice irrigation in southwestern Louisiana, where the average yield of irrigation wells is about 1,800 gpm. The potential yield of wells is less in the outcrop area because of the thinning of the aquifer.

The dissolved-solids content of the water is low in the outcrop areas of the coastal terraced deposits, as typified by the analysis of water from well R-463 (table 9). Mineralization of ground water increases downdip, as indicated by a comparison of the analyses of water from wells R-463 and Wa-54 with those of water from wells in the central and southern parts of the coastal area. (See table 9 and fig. 16.) The deposits in a large part of southwestern Louisiana and the northern part of southeastern Louisiana generally contain water having an objectionable quantity of iron. Wells R-463 and Wa-54, near the outcrop area, yield water having a relatively low pH and a high iron content. The water generally is soft in southeastern Louisiana; however, the water in southwestern Louisiana may increase in hardness as it moves downdip.

SUMMARY OF GROUND-WATER AVAILABILITY

Although Louisiana is considered to be a "water-rich" State there are several areas where little or no fresh ground water is available. As discussed in previous sections, the availability of ground water is intimately related to geologic structure and stratigraphy. The occurrence of ground water is summarized in two illustrations: (1) a map showing, by contours, the altitude of the base of the fresh water-bearing section (pl. 3), and (2) a map showing, by regions, the general quantity and quality of ground water available in the State (pl. 4).

ALTITUDE OF THE BASE OF FRESH WATER

The definition of the term "fresh water" is tempered by the quality of water that is available. Thus, at one locality water with a chloride content of 250 ppm could be considered either of inferior or good quality, depending on the availability of sufficient quantities of water of better quality, but at another location water of this same quality might be prized because of the scarcity of potable water. The contour map (pl. 3) was prepared on the basis of water whose chloride content was estimated to be 250 ppm or less because it is the upper limit of chloride content suggested by the U.S. Public Health Service (1946) for water used on interstate carriers.

The control on which plate 3 is based primarily is from the interpretation of electrical logs. Approximately 5,000 electrical logs were reviewed. Chemical analyses of water and records of water wells aided in the interpretation of the electrical logs and supplied data in some areas where electrical-log coverage was not available. The altitude of the base of fresh water in sands is shown by contours. Thus, to determine the depth to which fresh water occurs at any point, the altitude of the land surface must be considered in the following manner: where the depth to the base of fresh water is above sea level (+ contours), the altitude shown on the contour map (pl. 3) is subtracted from the altitude of the land surface; where the altitude of the base of fresh water is below sea level,

the altitude of the land surface is added to that shown on the contour map.

In some areas water-bearing sands above the altitude of the base of fresh water contain salty water. These intermediate salt water-bearing sands occur in the shaded areas on plate 3. The thickness and depth of these sands vary greatly; therefore, it is necessary to consult electrical logs and water-well records from these areas in order to define them accurately.

The base of fresh water reflects regional geologic structure and stratigraphy. Examples of three geologic settings which affect the base of fresh water are the Sabine uplift, the occurrence of the Jackson and Vicksburg groups, and the thickening of sediments toward the Gulf Coast geosyncline.

The near-surface position of the base of fresh ground water in northwestern Louisiana (pl. 3) corresponds to a structural high, the Sabine uplift. (See fig. 2.) The effect of this structural high is obvious if a comparison of the area of this ground-water high (pl. 3) is made with the geologic map and fence diagram (pls. 1 and 2). The structural high has uplifted the thick clay section of the Midway group to the land surface. The clay prevents the circulation of fresh water into and out of the deposits of Cretaceous age. Thus, the shallow occurrence of fresh water is due to a combination of geologic structure and stratigraphy in the area.

The Vicksburg-Jackson groups lie at or near the land surface in central Louisiana and trend east-northeast (pl. 1). The areas where these groups contain little or no fresh water are shown on plate 4 (5 B) and reflected on plate 3 by the near-surface altitude of the base of fresh water. As with the Midway group, the confining effect of a thick clay section restricts the flushing of salt water from the underlying formation. The dip of the Vicksburg-Jackson groups flattens near the northeastern border of the State (pl. 2), and the resulting broad belt of clay is blanketed by Quaternary deposits. These Quaternary deposits contain the only fresh water in Franklin and Ten-

sas Parishes and the western two-thirds of Madison Parish (pl. 3).

The great thickening of the Coastal Plain sediments toward the axis of the Gulf Coast geosyncline affects the depth of occurrence of fresh ground water. The beds of clay of the Vicksburg-Jackson groups act as a barrier to the downward movement of water from the Miocene deposits. These deposits dip and thicken rapidly toward the gulf and water from the relatively high recharge area moves downdip flushing salt water from the Miocene deposits. The depth and downdip limit of flushing are functions of the permeability of the sediments, the hydrostatic head, and the difference in density of the fresh and salt water. The southern limit of flushing of the Miocene and overlying Pliocene deposits is shown by the abrupt increase in the altitude of the base of fresh water along a zone roughly parallel to the coastline extending from the Texas border in northern Calcasieu Parish to the Mississippi border in southern St. Tammany Parish (pl. 3). The fence diagram (pl. 2) shows the wedgelike configuration of these sediments and the southern limit of fresh-water flushing. The southern limit of flushing is illustrated on plate 2 between wells 110 and 111 in western Louisiana and between wells 150 and 151 in eastern Louisiana. This great mass of sediments contains fresh water to the greatest known depth in the State—3,550 feet below the land surface (3,495 feet below mean sea level) near the eastern border of St. Tammany Parish.

Piercement-type salt domes have a pronounced local effect on the depth of occurrence of fresh water as illustrated by a comparison of plate 3 with figure 3. A description of salt domes and their effects on the occurrence of fresh ground water is included under the discussion of geologic structure.

QUANTITY AND QUALITY, BY REGIONS

A map showing the general availability of ground water in Louisiana was first presented in a report by Jones (1946). A revision of that map was included in the publication "Water" (1956, fig. 14), a special report to the

Louisiana legislature. Plate 4 was prepared from current data and is similar to the 1956 map, except for local revisions. On this map the State is divided into five major ground-water regions based on the quality and quantity of ground water available. These regions are further subdivided into areas to facilitate the following discussion.

Region 1

Moderate to large quantities of soft ground water generally are available in this region.

A. This area includes much of north-central Louisiana. Large supplies of water are available, chiefly from the Sparta sand. Wells generally are 100 to 900 feet deep, and most large-diameter wells yield 200 to 1,200 gpm; the largest known yield is about 2,000 gpm. Water levels generally range from 40 to 125 feet below the land surface, dependent chiefly on the altitude of the land surface and the local drawdown of water levels caused by pumping from wells. Water levels have declined to as much as 240 feet below the land surface in local areas of heavy withdrawals, such as Monroe.

B. This area includes most of Vernon and western Rapides Parishes, where moderate to large supplies of water are available from sands of Miocene age. Wells are as deep as 1,500 feet and yield as much as 1,200 gpm. Static water levels generally are below the land surface, as much as 100 feet in places, but the piezometric surface in areas of artesian pressure may be as much as 30 feet above the land surface. In the vicinity of Leesville concentrated withdrawals have lowered water levels to about 200 feet below the land surface.

C. Wells in this area, the northern two-thirds of southeastern Louisiana, yield large quantities of water from sands of Miocene, Pliocene, and Quaternary ages. Wells generally range in depth from 400 to 2,400 feet; the deepest is about 2,800 feet. Industrial wells have an average yield of about 1,000 gpm. The largest yield is in St. Tammany Parish, where a municipal supply well at Slidell had a flow of 3,200 gpm. Water levels on the west-

ern and southern margins of the area generally are below the land surface. Because of heavy withdrawals water levels have declined to as much as 140 feet below the land surface at Baton Rouge, 120 feet below the land surface at New Orleans, and 90 feet below the land surface at Norco. Flowing artesian wells are common in the remainder of the region; the highest known water level is about 125 feet above the land surface.

Region 2

Small to moderate quantities of soft water generally are available from deposits that range in age from Paleocene to Quaternary. The region is composed of several separate areas in northwestern and central Louisiana. Wells generally are not more than 300 to 400 feet deep and have yields that range from a few gallons per minute to about 500 gpm.

Region 3

Moderate to large quantities of hard water and small to large quantities of soft water are available in most places in the region.

A. Wells in these areas in the Red River Valley yield water from alluvial deposits of Quaternary age and from underlying deposits that range in age from Paleocene to Miocene. Wells in the alluvium seldom are more than 150 feet deep. These wells have yields of as much as 1,300 gpm of hard water. Water levels in the alluvial deposits generally are 20 to 30 feet below the land surface.

The underlying older deposits contain soft water but wells generally yield small to moderate quantities. Wells in the northern part of the valley generally are shallow, but some wells in the Alexandria area are about 1,200 feet deep. Yields of wells in the northern part of the valley range from a few gallons per minute to about 200 gpm. The average yield in the Alexandria area, however, is about 400 gpm. Water levels throughout most of the area generally are 20 to 30 feet below the land surface. In the Alexandria area concentrated withdrawals have lowered water levels to about 150 feet below the land surface.

B. Quaternary deposits yield large quantities of hard water to wells in central Louisiana, and the underlying deposits of Miocene and Pliocene ages yield small to large quantities of soft water. Wells completed in Quaternary deposits generally are 150 to 700 feet deep and have large yields. The maximum yield of a well in southwestern Louisiana is 6,000 gpm, and the average yield of wells for rice irrigation is 1,800 gpm. Wells completed in Miocene and Pliocene deposits yield soft water at rates that range from 300 to 1,500 gpm. Water levels generally are 10 to 50 feet below the land surface, but some wells flow at the surface. The highest water level measured in the area is 55 feet above the land surface at Krotz Springs in St. Landry Parish.

C. Quaternary alluvial deposits yield large quantities of hard water to wells in northeastern Louisiana, and the underlying Sparta sand and the Cockfield formation yield moderate to large quantities of softer water. Wells in the Quaternary deposits generally are less than 200 feet deep and have yields as large as 2,800 gpm. Water levels are within 20 feet of the land surface.

The western part of the area is underlain by the Sparta sand. Industrial wells in the Bastrop area generally are about 800 feet deep and yield as much as 1,700 gpm. Water levels generally are 25 feet or more below the land surface and are about 190 feet below the land surface in the area of heavy withdrawal at Bastrop.

The Cockfield formation in the eastern part of the area yields water to wells which range in depth from 225 to 450 feet. A maximum known yield of 700 gpm is from a well 445 feet deep at Lake Providence, East Carroll Parish. Water levels generally are 20 feet below the land surface, except at Lake Providence, where pumping from municipal-supply wells has caused water levels to decline to a depth of about 65 feet.

Region 4

Moderate to large quantities of hard water are available in this region.

A. Wells in the Quaternary valley deposits in the

Mississippi River and Red River valleys yield moderate to large quantities of hard water. Wells generally are 200 feet or less in depth and yields range from 250 gpm to more than 4,000 gpm. Static water levels are within 30 feet of the land surface throughout the area.

B. In southwestern Louisiana Quaternary sand and gravel yields large quantities of hard water to wells. Wells range in depth from 200 feet to more than 700 feet and yield as much as 4,000 gpm; yields generally range from 1,000 to 2,000 gpm. Water levels range in depth from about 20 to 70 feet below the land surface, except in the Lake Charles area, where concentrated pumping, principally industrial, has caused water levels to decline to about 110 feet below the land surface.

C. Quaternary deposits in these areas contain fresh water which grades downward to salt water within the same sand unit. Therefore, wells generally must be screened at a shallow depth and pumped at a low rate to prevent the pumping of salt water. Much of the area consists of coastal marshes, where ground-water resources are comparatively undeveloped.

Region 5

Little or no potable water is available in the scattered areas of this region.

A. The Wilcox group is the only aquifer in the area, and it is thin or absent from the geologic section. Sands in the Wilcox are fine grained and yields of wells generally are less than 50 gpm. Locally, ground water may be saline.

B. This area, through central Louisiana, corresponds to the outcrop belt of the Jackson and Vicksburg groups, which are composed principally of shale and marl and yield little or no water to wells. The underlying Cockfield formation contains fresh water in places, as do scattered, thin beds of sand and gravel of Quaternary age which cap the uplands.

C. In these coastal areas there is no fresh ground water except possibly thin lenses of fresh water floating on salt water.

TABLES 1-10

TABLE 1

GENERALIZED POST-CRETACEOUS STRATIGRAPHIC COLUMN FOR LOUISIANA

Era	System	Series	Group	Formation	Lithology and water-bearing characteristics.
Cenozoic	Quaternary	Pleistocene and Recent			Clay, sand, and gravel. Permeable deposits yield large quantities of water, which generally is hard. Yields of wells are as much as 6,000 gpm.
	Tertiary	Pliocene			Clay and sand. Sands yield moderate to large quantities of soft water, as much as 3,200 gpm.
		Miocene			Clay and sand. Sands yield moderate to large quantities of soft water. Wells tapping thick saturated sections may yield 1,500 gpm or more.
		Oligocene	Vicksburg		Carbonaceous shale and clay, and marl. Silt and very fine sand in the outcrop areas yield small quantities of water locally. Generally not considered water bearing.
		Eocene	Jackson		
			Claiborne	Cockfield	Clay and sand. Sands yield moderate quantities of water, which ranges from soft to very hard.
				Cook Mountain	Clay and marl. Generally not water bearing.
				Sparta sand	Sand and clay. Sands yield large quantities of soft water, as much as 2,000 gpm.
				Cane River	Clay and marl. Generally not water bearing. Interpretation of electrical logs of oil-test wells indicate that a sandy facies in northern Caddo and Bossier Parishes contains fresh water.
			Wilcox		Clay and sand. Sands yield small to moderate quantities of fresh water of variable quality. Water may be saline locally. Yields of wells may be as much as 500 gpm.
		Paleocene	Midway		Clay and shale. Not considered water bearing.

TABLE 2

NAMES AND LOCATIONS OF SALT DOMES SHOWN ON FIGURE 3

		Township	Range
	WEBSTER PARISH		
1.	Minden	19N	8W
2.	Bistineau	18N	10W
	BIENVILLE PARISH		
3.	Vacherie	17N	8W
4.	Gibsland	18N	7W
5.	Arcadia	18N	5W
6.	Kings	15N	8W
7.	Prothro	14N	6W
8.	Rayburns	15N	5,6W
	NATCHITOCHES PARISH		
9.	Chestnut	13N	6W
	WINN PARISH		
10.	Prices	13N	4,5W
11.	Drakes	12N	5W
12.	Coochie Brake	9,10N	4W
13.	Winnfield	11N	3W
14.	Cedar Creek	11N	2W
15.	Packton	10N	2W
16.	Castor Creek	10N	1E
17.	Sikes	12N	1W
	CALDWELL PARISH		
18.	Chester	13,14N	1,2E
	FRANKLIN PARISH		
19.	Crowville	15N	8E
20.	Gilbert	13N	8E
	MADISON PARISH		
21.	North Tallulah	17N	13E
22.	Walnut Bayou	17N	13,14E
23.	Singer	15,16N	11E
24.	Tallulah	16N	12E
25.	South Coleman	15N	13E
	TENSAS PARISH		
26.	Somerset	14N	11E
27.	Newellton	13N	12E
	CATAHOULA PARISH		
28.	Foules	10N	8,9E
	RAPIDES PARISH		
29.	Cheneyville	1S	2E
	EVANGELINE PARISH		
30.	Pine Prairie	3S	1W
	CALCASIEU PARISH		
31.	North Starks	8S	13W
32.	Starks	9S	12W
33.	Edgerly	9S	11W
34.	Sulphur Mines	9S	10W
35.	Lockport	10S	9W
36.	Vinton	10,11S	12W
	JEFFERSON DAVIS PARISH		
37.	Iowa	9S	6,7W
38.	Woodlawn	9S	5,6W

TABLE 2—Continued

		Township	Range
39.	Welsh	9S	5W
40.	Roanoke	9S	4W
	CAMERON PARISH		
41.	Black Bayou	12S	12,13W
42.	Hackberry, West	12S	10,11W
43.	Hackberry, East	12S	9,10W
44.	Cameron Meadows	14S	13W
45.	Calcasieu Lake	13S	9W
46.	Creole (Blk. 2, West Cameron Area)		
47.	Big Lake	12S	8,9W
48.	Sweet Lake	13S	8W
	ACADIA PARISH		
49.	Jennings	9S	2W
	VERMILION PARISH		
50.	Gueydan	11S	1W
	ST. LANDRY PARISH		
51.	Port Barre	6S	5,6E
	ST. MARTIN PARISH		
52.	Plumb Bob	8S	7E
53.	Anse la Butte	9S	5E
54.	Section "28"	9S	7E
55.	Lake Chicot	11S	9,10E
56.	Lake Mongoulois	10S	9E
57.	Bayou Bouillon	9S	8,9E
	IBERVILLE PARISH		
58.	Bayou des Glaises	8S	8E
59.	Bayou Choctaw	8,9S	11E
60.	Bayou Bleu	9S	10,11E
61.	St. Gabriel	9S	1,2E
62.	White Castle	11S	12E
	IBERIA PARISH		
63.	Fausse Pointe	11S	8E
64.	Iberia	12S	7E
65.	Jefferson Island	12S	5E
66.	Avery Island	13S	5,6E
67.	Weeks Island	14S	6,7E
68.	South Tigre Lagoon	14S	5E
69.	Vermilion Bay	15,16S	5,6E
	ST. MARY PARISH		
70.	West Cote Blanche Bay	15,16S	6,7E
71.	Cote Blanche Island	15S	7E
72.	Jeanerette	13S	8,9E
73.	Charenton	13S	9,10E
74.	Belle Isle	17,18S	10,11E
	ASCENSION PARISH		
75.	Darrow	10S	2E
76.	Sorrento	10S	4E
	ASSUMPTION PARISH		
77.	Napoleonville	12S	13E
	ST. JAMES PARISH		
78.	Hester	11,12S	4,5E
	TERREBONNE PARISH		
79.	Bay Junop	21S	14E
80.	Coon Point (Blk. 38)		
81.	Dog Lake	21,22S	15,16E

TABLE 2—Continued

		Township	Range
82.	Four Isle Bay	21S	16E
83.	Bay St. Elaine	22S	17,18E
84.	Lake Pelto	23S	17,18E
85.	Caillou Island	22,23S	19,20E
86.	Lake Barre	21S	19,20E
	ST. CHARLES PARISH		
87.	Paradis	14S	20E
88.	Bayou des Allemands	15S	20,21E
89.	Bayou Couba	15S	21,22E
	JEFFERSON PARISH		
90.	Barataria	15,16S	23E
	LAFOURCHE PARISH		
91.	Chacahoula	15S	15E
92.	Raceland	15S	19E
93.	Valentine	17S	20E
94.	Cut Off	17,18S	21E
95.	Bully Camp	18,19S	20,21E
96.	Clovelly	18,19S	22E
97.	Bay de Chene	19,20S	24E
98.	Leeville	21S	22E
99.	Timbalier Bay	23S	21E
100.	Bay Marchand	23S	22,23E
	PLAQUEMINES PARISH		
101.	Stella	14S	24E
102.	Lake Hermitage	18S	25E
103.	Potash	18S	15E
104.	Lake Washington	19,20S	26,27E
105.	Venice	22S	30E
106.	Delta Duck	21S	20E
107.	Garden Island Bay	23S	32,33E
108.	West Bay	22,23S	30,31E
	MAIN PASS AREA		
109.	Block 46[1]		
	WEST DELTA AREA		
110.	Block 30		
	GRAND ISLE AREA		
111.	Block 16		
112.	Block 18		
	SOUTH TIMBALIER AREA		
113.	Block 54		
114.	Block 86		
115.	Block 135		
	SOUTH PELTO AREA		
116.	Block 20		
	SHIP SHOAL AREA		
117.	Block 32		
118.	Block 72		
119.	Block 113		
120.	Block 154		
	EUGENE ISLAND AREA		
121.	Block 32		
122.	Block 77		
123.	Block 110		
124.	Block 126		
125.	Block 128		

TABLE 2—Continued

126. Block 175
127. Block 184
128. Block 188

VERMILION AREA

129. Block 102
130. Block 120

EAST CAMERON AREA

131. Block 126

[1]Blocks are a system of land division for the off-shore areas of Louisiana based on the Louisiana Lambert Plane Coordinate System (South Zone). (See Coignet, 1959.)

TABLE 3

CHEMICAL ANALYSES OF WATER FROM SANDS OF THE WILCOX GROUP

Well No.	Bo-141	Cd-325	DS-115	Na-233	RR-134	Sa-32
Parish	Bossier	Caddo	DeSoto	Natchitoches	Red River	Sabine
Depth, in feet	200	217	213	150	150	449
Date of collection	3-21-57	3-26-57	3-4-55	5-14-56	7-5-56	2-24-55
Chemical constituents (parts per million)						
Silica (SiO_2)	26	65	14	18	49	16
Total iron (Fe)	5.5	11	.22	5.2	3.3	.16
Iron in solution (Fe)	.08	.51	.21	.00	.37	.01
Manganese (Mn)	.03	.15	.00	.04	.20	.00
Calcium (Ca)	1.2	18	2.6	33	26	1.2
Magnesium (Mg)	.6	4.1	.4	31	3.6	.3
Sodium (Na)	4.2	15	247	390	14	533
Potassium (K)	1.0	2.0	1.4	7.5	1.6	1.9
Carbonate (CO_3)	0	0	18	0	0	47
Bicarbonate (HCO_3)	12	70	524	266	130	1,280
Sulfate (SO_4)	.2	.2	20	657	1.3	.1
Chloride (Cl)	4.0	29	45	120	2.5	23
Fluoride (F)	.0	.1	.4	.3	.1	3.6
Nitrate (NO_3)	.1	.0	3.5	2.4	.5	.5
Boron (B)	.06	.15	.08	.46	.03	....
Dissolved solids	43	175	613	1,390	166	1,300
Hardness as $CaCO_3$	5	62	8	210	79	4
Physical Properties						
Specific conductance (micromhos at 25°C)	38.5	198	1,020	2,090	208	2,030
Color	0	5	0	0	110	140
pH	5.7	6.4	8.3	7.4	7.5	8.5

TABLE 4

CHEMICAL ANALYSES OF WATER FROM THE SPARTA SAND OF THE CLAIBORNE GROUP

		Area 1		Area 2			Area 3[1]
Well No.		Na-100	Sa-8	Cl-57	Ja-4	Mo-65	Issaquena Co. 19
Parish		Natchitoches	Sabine	Claiborne	Jackson	Morehouse	Issaquena Co., Miss.
Depth, in feet		436	100	435	534	630	1,201
Date of collection		3-25-55	3-12-57	5-1-57	3-24-55	3-23-55	.....
Chemical constituents (parts per million)	Silica (SiO_2)	44	28	28	13	15	....
	Total iron (Fe)	1.1	.63	1.9	.09	.01	.69
	Iron in solution (Fe)	.56	.02	.01	.06	.01	....
	Manganese (Mn)	.04	.01	.01	.00	.00	....
	Calcium (Ca)	2.6	6.6	3.6	.3	1.4	1.43
	Magnesium (Mg)	1.0	3.8	1.6	.2	.0	.60
	Sodium (Na)	73	10	9.9	109	279	182.8
	Potassium (K)	1.6	2.4	3.0	1.6	1.2	....
	Carbonate (CO_3)	0	0	0	0	5	20
	Bicarbonate (HCO_3)	152	42	65	230	415	439
	Sulfate (SO_4)	27	9.6	.6	36	.2	.21
	Chloride (Cl)	10	8.8	6.2	8.5	185	20
	Fluoride (F)	.1	.1	.0	.0	.5	1.2
	Nitrate (NO_3)	1.5	.8	.0	2.5	1.2	....
	Boron (B)	.06	.00	.03	.17	.22	....
	Dissolved solids	237	91	118	297	695	470.8
	Hardness as $CaCO_3$	11	32	16	2	4	....
Physical Properties	Specific conductance (micromhos at 25°C)	335	120	....	464	1,230	....
	Color	0	0	....	0	40	....
	pH	7.8	6.1	6.6	7.3	8.4	....

[1] Analysis from Mississippi State Geol. Survey Bull. 65, p. 70.

TABLE 5

CHEMICAL ANALYSES OF WATER FROM SANDS OF THE COCKFIELD FORMATION OF THE CLAIBORNE GROUP

		Area 1		Area 2		
	Well No.	Na-9	Sa-213	Ca-8	EC-89	EC-129
	Parish	Natchitoches	Sabine	Caldwell	East Carroll	East Carroll
	Depth, in feet	1,300	145	270	374	500
	Date of collection	3-24-58	2-24-55	3-23-55	7-24-56	10-17-57
Chemical constituents (parts per million)	Silica (SiO_2)	24	38	54	24	12
	Total iron (Fe)	.24	6.8	7.5	1.5	.11
	Iron in solution (Fe)	.24	.43	.00	.07	.07
	Manganese (Mn)	.02	.20	.20	.04	.00
	Calcium (Ca)	.9	20	26	61	.5
	Magnesium (Mg)	.3	15	10	19	.0
	Sodium (Na)	235	35	31	22	328
	Potassium (K)	1.4	6.0	3.2	2.9	1.9
	Carbonate (CO_3)	27	0	0	0	24
	Bicarbonate (HCO_3)	505	156	109	330	753
	Sulfate (SO_4)	23	45	60	4.0	.2
	Chloride (Cl)	20	17	23	7.0	48
	Fluoride (F)	.5	.4	.1	.1	2.0
	Nitrate (NO_3)	.5	.2	.0	.8	.2
	Boron (B)	1.4	.09	.10	.11	2.4
	Dissolved solids	585	290	272	303	813
	Hardness as $CaCO_3$	3	111	106	231	1
Physical Properties	Specific conductance (micromhos at 25°C)	924	395	385	514	1,290
	Color	----	15	0	0	360
	pH	8.7	7.1	6.9	7.7	8.6

TABLE 6

CHEMICAL ANALYSES OF WATER FROM SANDS OF THE MIOCENE SERIES

	Well No.	Be-366	Co-3	EB-534	R-422	V-105	Wa-55
	Parish	Beauregard	Concordia	East Baton Rouge	Rapides	Vernon	Washington
	Depth, in feet	1,212	680	2,759	700	912	1,534
	Date of collection	12-19-55	12-29-50	1-10-55	9-25-56	7-31-57	7-3-57
Chemical constituents (parts per million)	Silica (SiO_2)	18	43	26	46	80	44
	Total iron (Fe)	.03	.26	.05	....	.33	.06
	Iron in solution (Fe)	.02	....	.00	.03	.25	.02
	Manganese (Mn)	.01	....	.00	....	....	.01
	Calcium (Ca)	1.8	1.2	1.2	2.8	12	.4
	Magnesium (Mg)	.2	1.0	.2	.3	.4	.0
	Sodium (Na)	78	266	177	264	40	48
	Potassium (K)	.9	2.8	.8			.4
	Carbonate (CO_3)	trace	0	0	0	0	0
	Bicarbonate (HCO_3)	195	332	417	642	105	104
	Sulfate (SO_4)	8.7	.5	3.6	.7	6.8	8.6
	Chloride (Cl)	6.0	218	33	33	18	6.8
	Fluoride (F)	.6	.6	1.1	2.8	.4	.0
	Nitrate (NO_3)	.3	.0	.0	1.5	.0	.2
	Boron (B)	.14	2.9	.41	....	....	.03
	Dissolved solids	211	730	457	664	209	162
	Hardness as $CaCO_3$	5	7	4	8	32	1
Physical Properties	Specific conductance (micromhos at 25°C)	329	1,160	723	1,030	241	202
	Color	0	140	35	5	5	0
	pH	8.5	7.9	8.2	8.5	6.5	7.5

TABLE 7

CHEMICAL ANALYSES OF WATER FROM SANDS OF THE PLIOCENE SERIES

		Area 1		Area 2			
	Well No.	Al-157	Ev-142	EB-621	SL-166	ST-565	Wa-18
	Parish	Allen	Evangeline	East Baton Rouge	St. Landry	St. Tammany	Washington
	Depth, in feet	706	989	1,487	1,862	1,968	788
	Date of collection	1-31-55	2-7-50	7-31-57	12-21-54	11-20-57	2-31-57
Chemical constituents (parts per million)	Silica (SiO_2)	34	25	31	29	26	56
	Total iron (Fe)	.38	.6	.30	.08	.02	1.6
	Iron in solution (Fe)	.16	....	.01	.06	.02	.49
	Manganese (Mn)	.00	....	.00	.3	.01	.10
	Calcium (Ca)	1.2	.6	1.5	.2	.4	4.7
	Magnesium (Mg)	.0	.7	.0	.3	.1	1.5
	Sodium (Na)	168	195	70	129	131	9.3
	Potassium (K)	.6	5.2	.5	.4	.8	3.4
	Carbonate (CO_3)	6	0	3	20	14	0
	Bicarbonate (HCO_3)	406	397	166	281	298	33
	Sulfate (SO_4)	.2	1.1	9.8	7.3	11	11
	Chloride (Cl)	14	66	4.5	8.2	6.5	3.0
	Fluoride (F)	1.1	5.2	.2	.7	.7	.1
	Nitrate (NO_3)	.5	1.2	.5	.0	.2	.2
	Boron (B)	.28	1.3	.05	.17	.27	.08
	Dissolved solids	430	508	204	334	338	106
	Hardness as $CaCO_3$	3	4	4	2	2	18
Physical Properties	Specific conductance (micromhos at 25°C)	654	809	299	533	527	92.8
	Color	120	70	0	40	15	15
	pH	8.3	8.2	8.4	8.8	9.0	6.4

TABLE 8

CHEMICAL ANALYSES OF WATER FROM QUATERNARY VALLEY DEPOSITS

	Well No.	Av-33	EB-100	I-53	Ma-25	RR-50
	Parish	Avoyelles	East Baton Rouge	Iberia	Madison	Red River
	Depth, in feet	103	338	210	166	105
	Date of collection	2-16-55	5-9-51	10-19-49	9-12-57	2-9-55
Chemical constituents (parts per million)	Silica (SiO_2)	44	34	46	33	26
	Total iron (Fe)	.41	1.3	6.8	19	4.4
	Iron in solution (Fe)	.00	.08	....	.02	.01
	Manganese (Mn)	....	.05	....	1.00	....
	Calcium (Ca)	61	62	102	106	102
	Magnesium (Mg)	26	18	39	27	55
	Sodium (Na)	130	20	32	12	56
	Potassium (K)	1.8	2.4	8.8	3.7	1.6
	Carbonate (CO_3)	0	0	0	0	0
	Bicarbonate (HCO_3)	261	314	613	494	545
	Sulfate (SO_4)	162	1.0	.6	.8	73
	Chloride (Cl)	117	7.2	5.0	5.2	62
	Fluoride (F)	.2	.1	.5	.2	.3
	Nitrate (NO_3)	5.4	2.5	0	.0	3.0
	Boron (B)	.00	.19	....	.16	.00
	Dissolved solids	678	300	535	432	657
	Hardness as $CaCO_3$	259	228	415	376	480
Physical Properties	Specific conductance (micromhos at 25°C)	1,090	505	871	735	1,080
	Color	0	....	20	0	0
	pH	6.9	7.5	7.2	7.3	7.2

TABLE 9

CHEMICAL ANALYSES OF WATER FROM QUATERNARY UPLAND DEPOSITS

Well No.	Cu-675[1]	Cn-10[1]	EB-360[1]	Ev-520[1]	G-29[2]	Or-100[1]	R-463[1]	RR-97[2]	Wa-54[1]
Parish	Calcasieu	Cameron	East Baton Rouge	Evangeline	Grant	Orleans	Rapides	Red River	Washington
Depth, in feet	511	282	442	195	30	580	138	60	159
Date of collection	1-10-56	5-25-50	1-26-45	12-7-53	9-18-39	1-13-55	12-30-50	6-16-55	7-3-57
Chemical constituents (parts per million)									
Silica (SiO_2)	54	26	49	51	9.7	36	23	22	34
Total iron (Fe)	.85	.12	.16	2.3	1.2	.25	5.8	1.0	1.2
Iron in solution (Fe)	.16	....	....	.53	.1	.24	.04	.03	.11
Manganese (Mn)	....	....	....	.14	....	.00	....	.01	.08
Calcium (Ca)	34	27	21	22	1.2	2.0	1.6	.8	11
Magnesium (Mg)	8.8	8.7	5.8	12	.7	1.7	1.2	.3	2.8
Sodium (Na)	48	219	31	28	2.1	220	5.2	3.2	16
Potassium (K)		17	5.2	1.0	.6	2.2	.8	1.5	2.9
Carbonate (CO_3)	0	0	0	0	0	0	0	0	0
Bicarbonate (HCO_3)	182	305	158	146	6.0	385	18	42	66
Sulfate (SO_4)	2.6	.3	6.3	2.8	1.3	.1	.8	.6	9.6
Chloride (Cl)	51	241	10	32	2.6	131	4.0	4.2	10
Fluoride (F)	.1	.1	0	.1	.1	.4	.1	.0	.0
Nitrate (NO_3)	.2	1.0	0	.0	1.8	.0	.0	1.0	.2
Boron (B)	....	.14	....	.05	....	.43	.03	.02	.00
Dissolved solids	288	690	219	222	24	590	49	60	121
Hardness as $CaCO_3$	120	104	76	104	5.9	12	9	3	39
Physical Properties									
Specific conductance (micromhos at 25°C)	440	1,210	291	323	....	963	54	87.5	161
Color	5	....	....	20	....	160	....	0	0
pH	7.5	7.6	7.6	7.0	....	8.0	5.8	6.8	5.7

[1] Screened in coastwise terraced deposits
[2] Screened in upland terraced deposits

TABLE 10

OIL—TEST AND WATER WELLS SHOWN ON PLATE 2

Number on Plate 2	Location Sec.	T.	R.	Company	Well
	Caddo Parish				
1	12	23N.	16W.	Arkla Oil Co.	Mattie Pitts No. 3
2	3	23N.	15W.	Arkla Oil Co.	A. B. Cole No. 2
	Bossier Parish				
3	11	23N.	14W.	Hunt Oil Co.	M. B. Rogers, et al., Unit No. 1
4	3	23N.	13W.	The Carter Oil Co.	W. E. Hall, et al., No. 1
5	10	23N.	12W.	Hunt Oil Co., et al.	Nebo Oil Co., Inc., Unit No. 1
	Webster Parish				
6	11	23N.	11W.	Shell Oil Co.	Gladys Braley No. 1
7	12	23N.	10W.	Exploration Drilling Co.	International Paper Co. No. 1
8	17	23N.	9W.	The Carter Oil Co.	Aubrey C. Sanders No. 1
	Claiborne Parish				
9	17	23N.	8W.	Midstates Oil Corp.	H. R. Smith No. 1—Deep
10	16	23N.	7W.	Zach Brooks Drilling Co.	Green Unit No. 2
11	10	23N.	6W.	C. M. Roberson	Mrs. Juanita Richardson No. 1
12	13	23N.	5W.	Gulf Refining Co.	E. W. Gill, et al., No. 1
	Union Parish				
13	10	23N.	3W.	Sam Sklar, et al.	David Smith No. 1
14	13	23N.	1W.	Terrell Petroleum Co.	L. G. Gatson No. B-1
15	4	23N.	2E.	Monla Gas Co., Inc.	Monla Gas Co., Inc., Fee No. 1
	Morehouse Parish				
16	9	23N.	4E.	Southern Carbon Co.	Tensas Delta No. B-12
17	3	23N.	6E.	Union Producing Co.	Crossett No. C-1
18	16	23N.	7E.	Barnsdall Oil Co.	Crossett No. 1
19	27	23N.	8E.	Vernon Whitely Drilling Co.	W. A. Ober No. 1
	West Carroll Parish				
20	36	23N.	10E.	The Pure Oil Co.	Costello No. 1

	DeSoto Parish				
21	36	12N.	16W.	Sinclair Oil and Gas Co.	Mae Fletcher Unit No. 1
22	33	12N.	15W.	Nortex Oil and Gas	Carroll No. 1 Unit
23	28	12N.	14W.	Kerr-McGee Oil Industries, Inc.	Nabors No. 1
24	28	12N.	12W.	Nabors Drilling Co., Inc.	Jeff Williams No. 1
25	29	12N.	11W.	Kimball and Bohner	Matthews No. B-1
	Red River Parish				
26	25	12N.	11W.	Sam Sklar	Michael Le Long No. 1
27	4	11N.	9W.	Kenilworth Oil Corp., et al.	Longbell Petroleum Co. 1-A
	Natchitoches Parish				
28	13	12N.	8W.	Nebo Oil Co.	Nebo Fee No. 34
29	30	12N.	6W.	Continental Oil Co.	Pardee Co. No. A-1
30	27	12N.	6W.	Continental Oil Co.	Edenborn Inc. No. 1
	Winn Parish				
31	24	12N.	5W.	H. L. Hunt	Nebo Oil Co. Fee No. 143
32	36	12N.	3W.	E. L. Sauer	Birl Shirley No. 1
33	36	12N.	2W.	R. D. Bevill, Jr., Trustee	Sanders No. 1
34	1	11N.	1W.	Magnolia Petroleum Co.	Urania Lumber Co. No. 9
35	2	11N.	1E.	Magnolia Petroleum Co.	Urania Lumber Co. No. 5
	Caldwell Parish				
36	8	11N.	2E.	C. McGhee and C. N. Valerius	Urania Lumber Co. No. 1
37	12	11N.	2E.	H. L. Hunt	La. Central Oil and Gas Co. No. H-1
38	1	11N.	3E.	Big West Drilling Co.	R. G. Cruse No. 1
39	2	11N.	5E.	Nebo Oil Co.	Nebo Oil Co. Fee No. 2
	Franklin Parish				
40	5	11N.	6E.	Roy L. Fisher	Tensas Delta Land Co. 1-A
41	1	11N.	6E.	J. B. White, et al.	A. N. Dailey No. 1
42	1	11N.	7E.	Grubb and Hawkins	J. H. Cambell No. 1
43	34	12N.	8E.	Sohio Producing Co.	Mrs. E. E. Splane No. 1
	Tensas Parish				
44	22	12N.	10E.	Jett Drilling Co.	Fisher No. B-1
45	32	12N.	11E.	Jett Drilling Co.	West No. 1
	Beauregard Parish				
46	33	6S.	11W.	Magnolia Petroleum Co.	Musser-Davis No. 1
47	25	6S.	10W.	Humble Oil and Refining Co.	Edgewood Land and Logging Co., Ltd., No. B-1
48	25	6S.	9W.	Texas Co.	Mrs. Ida Hollingsworth No. 1
49	28	6S.	8W.	Texas Gulf Producing Co.	T. H. Bayne No. 1

TABLE 10—Continued

Number on Plate 2	Location Sec.	T.	R.	Company	Well
	Allen Parish				
50	25	6S.	7W.	Kimbark Co., Ltd. and Highlander Oil Co., Inc.	J. A. Bel, et al., No. 1
51	29	6S.	5W.	R. R. Frankel	Leo W. Wofford No. 1
52	19	6S.	4W.	Humble Oil and Refining Co.	J. C. Rostrum No. 1
53	22	6S.	3W.	Bel Oil Corp.	Bel Estate No. 1
	Evangeline Parish				
54	24	6S.	2W.	Texas Co.	Valin Vidrine No. 1
	St. Landry Parish				
55	46	6S.	2E.	Tide Water Associated Oil Co.	E. Darbonne No. 1
56	32	6S.	3E.	Southwestern Oil and Refining Co.	Sam Haas Estate No. 1
57	121	6S.	4E.	Pan American Production Co.	Leonie M. White No. 1
58	22	6S.	5E.	Texas Co.	Botany Bay Lumber Co. No. 48
59	25	6S.	6E.	Humble Oil and Refining Co.	Virginia Prince No. 4
	Pointe Coupee Parish				
60	41	6S.	8E.	N. B. Hunt	Bomer Banks Lumber Co. No. 1
61	29	6S.	10E.	N. B. Hunt	Henry M. Kimball No. 1
	West Baton Rouge Parish				
62	3	7S.	11E.	Sohio Petroleum Co.	Southern Land Products Co. No. 1
	East Baton Rouge Parish				
63	44	6S.	1E.	Sugarfield Oil Co.	Jones Estate No. 1
	Livingston Parish				
64	27	6S.	3E.	Town of Walker	Li-57
65	18	7S.	5E.	Gaylord Container Corp.	Gaylord Container Co. Fee No. 1
66	2	7S.	6E.	St. Margaret's Catholic Church	Li-54
	Tangipahoa Parish				
67	39	6S.	8E.	Billups	Ta-264

			Caddo Parish		
68	12	22N.	16W.	Kendrick Bros.	Bostwick No. 1
69	12	21N.	16W.	Stanolind Oil and Gas Co.	U. S. A.-Stanolind No. 1
70	12	20N.	16W.	Marshall and McCain	Arkla Gas Fee No. A-2
71	11	19N.	16W.	Burnham and Browning, et al.	Noel Estate B-1
72	11	18N.	16W.	R. W. Norton, Jr.	Mrs. B. L. Croom No. 1
73	2	17N.	16W.	Union Producing Co.	Trosper A-7
74	35	17N.	16W.	Atlas Oil and Refining Co.	C. R. Minor, et al., No. 1
75	23	16N.	16W.	Bert Fields	Thigpen-Herold No. 1
76	24	15N.	16W.	J. M. Harper, Jr.	Bogan-Smith Fee No. 1
77	11	14N.	16W.	Jones-O'Brien, Inc.	Keatchie Investment Corp. No. 3
			DeSoto Parish		
78	30	14N.	15W.	J. R. Butler Co.	S. E. Johnson No. 1-G
79	31	13N.	15W.	McDowell and Cook, Inc.	G. W. Moncrief No. 1
			Union Parish		
80	27	23N.	1W.	Taylor-Kirby Drilling Co.	Boone No. 1
81	22	22N.	1W.	Sellars and Ewing Oil Interests	J. C. Williams, Sr. No. 1
82	3	21N.	1W.	R. Fred Petty-C. E. Wilds	P. J. Tucker No. 1
83	11	20N.	1W.	Carter Oil Co.	Willie Mae Stancil No. 1
			Lincoln Parish		
84	16	18N.	1W.	E. C. Wentworth Oil Co.	O'Neal No. 1
			Jackson Parish		
85	6	16N.	1E.	Texas Co.	Tremont Lumber Co. No. 1
86	22	15N.	1W.	Shell Oil Co., Inc.	Tremont Lumber Co. No. 1
87	35	14N.	1W.	The Brown Paper Mill Co., Inc.	The Brown Paper Mill Co. Fee No. 3
			East Carroll Parish		
88	22	23N.	12E.	Placid Oil Co.	Millikin No. 1
89	2	21N.	12E.	Sidney Frohman	Hamley No. 1
90	11	20N.	12E.	McAlester Fuel Co.	Robert Pettyfoot No. 1
91	26	20N.	12E.	Barnwell Drilling Co.	J. P. Brown No. 1
92	44	18N.	13E.	McAlester Fuel Co.	Pearl F. Brown No. 1
			Madison Parish		
93	36	18N.	12E.	Curtis Kinard	Sondheimer No. 1
94	44	17N.	13E.	H. Barksdale Brown and Co.	J. K. Mahoney No. 1
95	40	15N.	13E.	Continental Oil Co.	R. B. Watts No. 1
			Tensas Parish		
96	10	12N.	13E.	Jett Drilling Co.	Jacoby No. 1

TABLE 10—Continued

Number on Plate 2	Location Sec.	T.	R.	Company	Well
	Natchitoches Parish				
97	7	10N.	10W.	A. K. Busada	Abe Schmitt, et al, No. 1
98	19	10N.	10W.	S. E. Prichard	R. O. Martin No. 1
99	28	9N.	10W.	J. Downs	Dixon No. 1
	Sabine Parish				
100	11	8N.	11W.	J. J. Lynn	4 L No. 3
101	7	7N.	10W.	Rountree and Van Sant	Smith No. 1
102	2	6N.	11W.	A. J. Hodges Ind., Inc.	4 L Lumber Co. No. S-4
103	14	4N.	11W.	The Carter Oil Co.	Pickering Lumber Co., No. 1
	Vernon Parish				
104	11	2N.	11W.	Humble Oil and Refining Co.	Anderson Post Hardwood Lumber Co., Inc. No. 1
	Newton County				
105	Texas			Boger and Boger	Godfrey and Brown No. 1
	Vernon Parish				
106	3	2S.	9W.	Sunray Oil Corp.	Fletcher Estate No. 1
	Beauregard Parish				
107	35	3S.	11W.	The Atlantic Refining Co.	F. Thackery, et al., No. 1
108	24	4S.	11W.	Pan American Production Co.	Rice Land and Lumber Co. No. 1
109	22	5S.	11W.	Magnolia Petroleum Co.	Lutcher-Moore No. C-2
	Calcasieu Parish				
110	1	8S.	11W.	Sun Oil Co.	Sun Fee Salt Water Disposal No. 1
111	19	9S.	10W.	Magnolia Petroleum Co.	B. Ulrich No. 1
112	5	10S.	10W.	Union Sulphur and Oil Corp.	American Oil and Sulphur Co. No. 2
113	17	11S.	10W.	Union Sulphur and Oil Corp.	Eugene Ellender, et al., No. 1
	Cameron Parish				
114	7	12S.	10W.	Stanolind Oil and Gas Co.	State Land Lease 42 No. 97
115	24	12S.	11W.	Shell Oil Co.	Mrs. J. B. Watkins No. 1
116	18	14S.	10W.	Magnolia Petroleum Co.	Vincent Estate No. 1
117	1	15S.	11W.	Austral Oil Exploration Co., Inc.	Ray B. Peveto, et al., No. 1

			Franklin Parish		
118	3	11N.	7E.	Shell Oil Co.	M. W. Anderson No. 1
			Catahoula Parish		
119	28	10N.	7E.	N. B. Hunt and Lamar Hunt Trust Estate	Louisiana Central Minerals Co. No. 2
120	27	9N.	7E.	Olin Gas Transmission Corp.	Tensas-Delta No. 1
121	34	8N.	7E.	Penrod Drilling Co.	P. L. Mitchell No. 2
			Concordia Parish		
122	26	7N.	7E.	H. L. Hunt, et al.	Fisher Lumber Corp. No. E-20
			Catahoula Parish		
123	26	6N.	7E.	E. C. Wentworth	Lawrence No. 1
			Concordia Parish		
124	4	4N.	7E.	Barnett Serio Drilling Co.	B. E. Quinn No. 2
125	33	4N.	7E.	Barnett Serio Drilling Co.	Angelina Lumber Co. No. 3
126	17	3N.	7E.	Hunt Oil Co.	Metropolitan Museum of Arts, et al., No. 10
			Avoyelles Parish		
127	11	2N.	7E.	Placid Oil Co.	Southwestern Improvement Company No. 1-D
			Pointe Coupee Parish		
128	84	1S.	7E.	Humble Oil and Refining Co.	W. R. Buffington No. 1
			St. Landry Parish		
129	2	3S.	6E.	Crosby Drilling Corp.-Lyle Cummins	Eugene Gordon No. 1
130	28	4S.	6E.	The Atlantic Refining Co.	Brewer-Nienstedt No. 1
131	9	6S.	7E.	William Helis	Haas-Hirsch No. 1
132	5	7S.	7E.	Gulf Refining Co.	Krotz Springs Unit No. 22
			St. Martin Parish		
133	22	8S.	7E.	Southern Natural Gas Co.	Thomas L. Bernard, et al., No. 1
134	32	9S.	7E.	Freeport Sulphur Co.	J. J. Martin, et al., No. 5
135	4	11S.	7E.	Rowan Oil Co.-Texas Pacific Coal and Oil Co.	A. R. Fuselier No. 1
			Iberia Parish		
136	94	11S.	7E.	Humble Oil and Refining Co.	Leon Braquet No. 1
137	42	12S.	7E.	Phillips Petroleum Co.	W. B. Stewart No. 1
138	41	14S.	7E.	Shell Oil Co.	Smith "A" State Unit F No. 1
139	18	14S.	7E.	Shell Oil Co.	Smith State Unit "C" No. 6
140	44	14S.	7E.	Humble Oil and Refining Co.	J. M. Burguieres No. B-4

TABLE 10—Continued

Number on Plate 2	Location Sec.	T.	R.	Company	Well
	St. Mary Parish				
141	....	15S.	7E.	Texas Co.	West Cote Blanche Bay No. 38
142	....	16S.	7E.	Texas Co.	West Cote Blanche Bay No. 82
	Washington Parish				
143	45	1S.	14E.	Humble Oil and Refining Co.	Gaylord Container Corp. No. F-1
144	25	2S.	12E.	Humble Oil and Refining Co.	Gaylord Container Corp. No. 1
145	38	3S.	13E.	City of Bogalusa	Wa-53
146	15	4S.	12E.	Eagle Drilling and Development Co.	Gaylord Container Corp. No. 1
	St. Tammany Parish				
147	14	6S.	13E.	R. W. Woods	St-17
148	34	6S.	13E.	Southeastern Drilling Co.	Gaylord Container Corp. No. 1
149	Lake Pontchartrain			The Lynn Oil Co., et al.	State Lease 1713 Well No. 1
	Orleans Parish				
150	....	10S.	13E.	W. T. Burton	State Lake Pontchartrain No. 1
151	1	11S.	13E.	Richardson and Bass	Humble-Faubourg de Montluzin No. 1-H
	Plaquemines Parish				
152	31	14S.	13E.	S. W. Richardson	Selma Moss No. 1-D
153	6	17S.	25E.	William Helis	Louisiana Citrus Lands Inc. No. 1
154	2	18S.	25E.	Humble Oil and Refining Co.	Lake Hermitage Unit 1-B No. 1
155	17	20S.	26E.	John W. Mecom and Richardson and Bass (La. Account)	State Lease 1891 E. C. Cockrell No. 1-E
	Jefferson Parish				
156	Grand Isle Block 18			Humble Oil and Refining Co.	State Lease 796 No. H-1
157	Grand Isle Block 18			Humble Oil and Refining Co.	State Lease 802 No. C-1

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INDEX

References in bold face refer to figures

Alexandria, 51
Allen Parish, 40
Altitude of base of fresh water, 2, 31, 47-49
Artesian conditions, 16, 33
Avoyelles Parish, 38
Bastrop, 52
Baton Rouge, 7, 40, 51
Bienville Parish, **14, 15**
Bornhauser, Max, 10, 12
Bossier Parish, 23, 26
Caddo Parish, **22**, 23, 26
Calcasieu Parish, 49
Cane River formation, 24, **25**, 26
Chicot reservoir, 44
Chloride, 18
Claiborne group, 12, 24, **25**
Claiborne Parish, 29
Clayton formation, 19
Coastwise terraces, 44, 45
Cockfield formation, 1, 12, 24, **25**, 30, 31, **32**, 33, 52, 53
Concordia Parish, 38
Contamination, 21, 44
Cook Mountain formation, 24, **25**, 30
Cretaceous system, 19
DeSoto Parish, 24
Discharge, 17, 21, 27, 29, 31, 39, 42
Dissolved solids, 17
Durham, C. O., Jr., 19, 20
East Carroll Parish, 30, 52
Electrical logs, **5**
  Spontaneous potential curves, **5-7**
  Resistivity curves, 5-7
  of Midway group, **20**
  of Wilcox group, **22**
  of Claiborne group, **25**
  of Jackson and Vicksburg groups, **34**
  of Miocene, Pliocene, and Quaternary deposits, **36**
Fader, S. W., 44
Fisk, H. N., 9, 10, 12, 41
Fluoride, 18
Foley formation, 38
Franklin Parish, 48
Ground Water, principles of occurrence
  Recharge, 16
  Discharge, 17
  Movement, 17
Gulf Coast geosyncline, 10, 11, 28, 30, 48, 49
Harder, A. H., 44
Hardness, 17
Howe, H. V., 11, 12
Iron, 18
Issaquena County, Miss., 30
Jackson group, **34**, 35, 48, 53
Jackson Parish, 29
Jones, P. H., 10, 28, 38, 41, 44, 49
Krotz Springs, 52
Lake Charles, 53
Lake Providence, 30, 52
Leesville, 50
Lohr, E. W., 18
Madison Parish, 49
Maher, J. C., 38
Mamou member, 38
Martin, J. L., 24, 31
Meyer, R. R., 38
Midway group, 19, **20**
Minden, 28
Miocene series, 2, 9, 11, 35, **36**, **37**, 38, 50, 52
Mississippi River valley, 43, 53
Mississippi structural trough, 11, 28, 30, 35
Mobile-Tunica flexure, 12
Monroe, 28, 50
Monroe uplift, 10, 12
Morehouse Parish, 29, 30
Movement of ground water, 17, 28, 33, 35, 43, 44
Murray, G. E., Jr., 12, 20
Nacatoch sand, 19
Natchitoches Parish, 24, 31
Newcome, Roy, Jr., 21
New Orleans, 7, 51
Nitrate, 18
Norco, 51
Oakdale, 40
pH, 18
Pleistocene, 10, 41
Pliocene series, 2, 10, **36**, 38, **39**, 40, 41, 50, 52
Porters Creek clay, 19, **20**
Principles of occurrence of ground water, 16, 17
Quaternary system, 2, **36**, 41, **42**, 43, 44, 45, 50-53
  Valley deposits, 42, 43
  Upland deposits, 43-45
Quality of Water, 17, 18, 49-53
  from Wilcox, 23, 24, **69**
  from Sparta, 28, 29, **70**
  from Cockfield, 32, 33, **71**
  from Miocene, 37, 38, **72**
  from Pliocene, 40, 41, **73**
  from Quaternary valley deposits, 43, **74**
  from Quaternary terraced deposits, 44, **75**
  from Quaternary coastwise terraces, 45, **75**
Rangia johnsoni, 9, 35, 38
Rapides Parish, 31, 38, 50
Rayburns dome, 12, 13, **14, 15**
Recent deposits, 1, 41
Recharge, 16, 21, 23, 27, 28, 31, 33, 39, 42, 44, 48, 49
Red River Parish, 23
Red River Valley, 21, 27, 31, 51, 53
Resistivity curves, 5-7
Sabine Parish, 24, 31
Sabine River valley, 27
Sabine uplift, 10, 12, 19, 48
St. Landry Parish, 39, 52
St. Tammany Parish, 49, 50
Salt domes, 12-15, **13**, 49
  Rayburns dome, 12
  Weeks Island, 14
Sedimentation, post-Cretaceous, 9
Slidell, 40, 50
Smith, Chester R., 24
Southern Mississippi uplift, 10, 12
South Louisiana Geological Society, 12
Sparta sand, 1, 12, 24, 25, 26, 27, 28-30, 50, 52
Spontaneous potential curve, 5-7
Spooner, 26
Steep Gully member, 38

Stratigraphy, 9, 10
Structure, 10-16
Gulf Coast geosyncline, 10, 11
Mississippi structural trough, 11
Sabine uplift, 10, 12
Monroe uplift, 10, 12
Southern Mississippi uplift, 10, 12
Tensas Parish, 48
Terraced deposits, 43-45
Tertiary system, 19-41
Union Parish, 21, 22
Upland deposits, 43-45
U. S. Public Health Service, 18, 41, 43, 47
Valley deposits, 42-43
Vermilion River, 44
Vernon Parish, 31, 50
Vicksburg group, 34, 35, 48, 53
Waring, F. H., 18
Washington Parish, 10, 35
Water lands, 50-53
Water-table conditions, 16, 33
Webster Parish, 24
Weeks Island, 14
Well yields, 1-2, 23, 27, 29, 30, 31, 33, 37, 40, 43, 45, 50-53
West Carroll Parish, 30
Wilcox group, 1, 12, 13, 20, 21, 22, 23, 24, 53
Winn Parish, 21, 22

2313-B, 12-60

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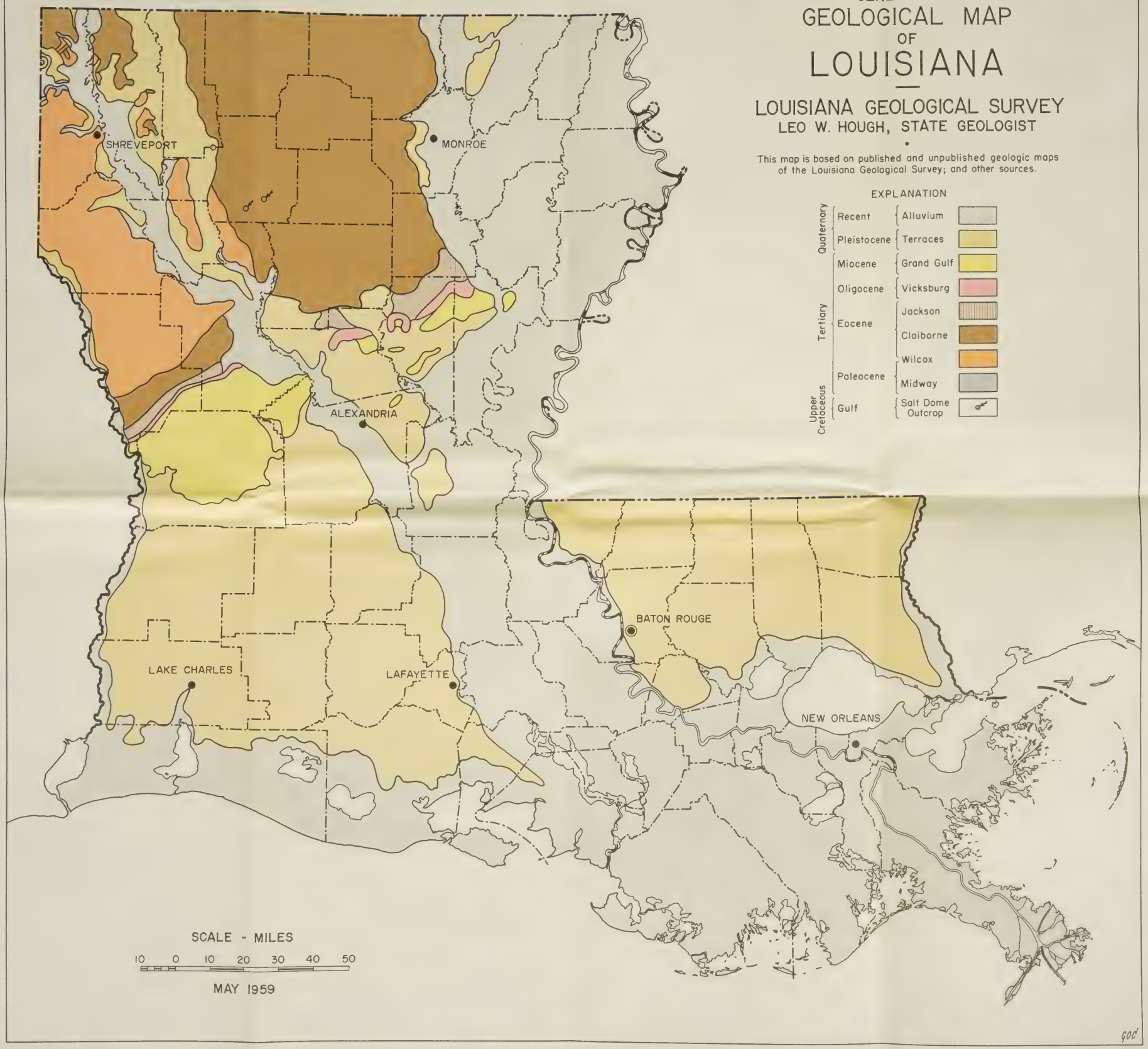

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Geology

FENCE DIAGRAM
SHOWING
SUBSURFACE GEOLOGY
OF
LOUISIANA

EXPLANATION

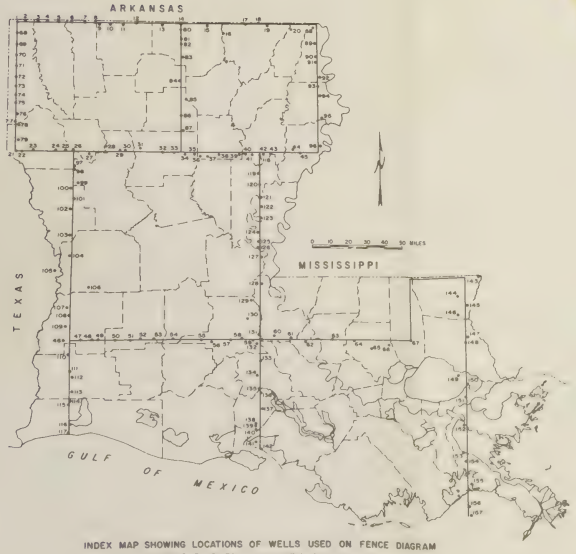
Recent Pleistocene		Q	QUATERNARY
Pliocene		Tp	
Miocene		Tm	
Oligocene	Vicksburg	Tvj	
	Jackson		
Eocene	Claiborne	Tc Cockfield; Tcm Cook Mountain; Ts Sparta; Tcr Cane River	TERTIARY
Eocene-Paleocene	Wilcox	Tw	
Paleocene	Midway	Tmy	
Undifferentiated		K	CRETACEOUS

0 5 10 15 20 25 30 MILES

Maximum depth to which fresh ground water occurs, intermediate sands may contain salt water

FEET
SEA LEVEL
200 400 600 800 1000 1200 1400 1600 1800 2000 2200 2400 2600 2800 3000 3200 3400 3600

Tm — WEEKS ISLAND SALT DOME



INDEX MAP SHOWING LOCATIONS OF WELLS USED ON FENCE DIAGRAM
(SEE TABLE 10 FOR DESCRIPTIONS OF WELLS)

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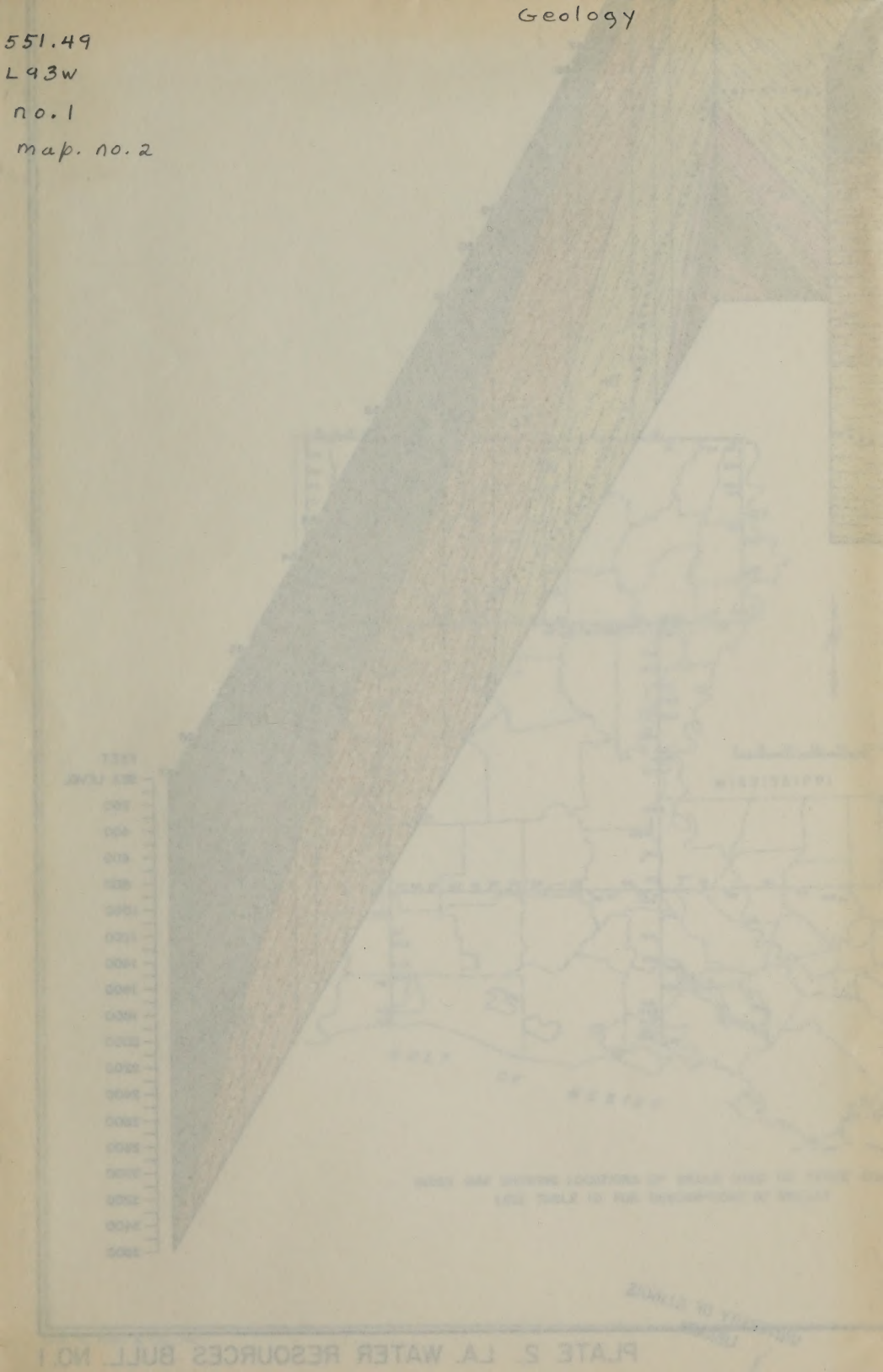

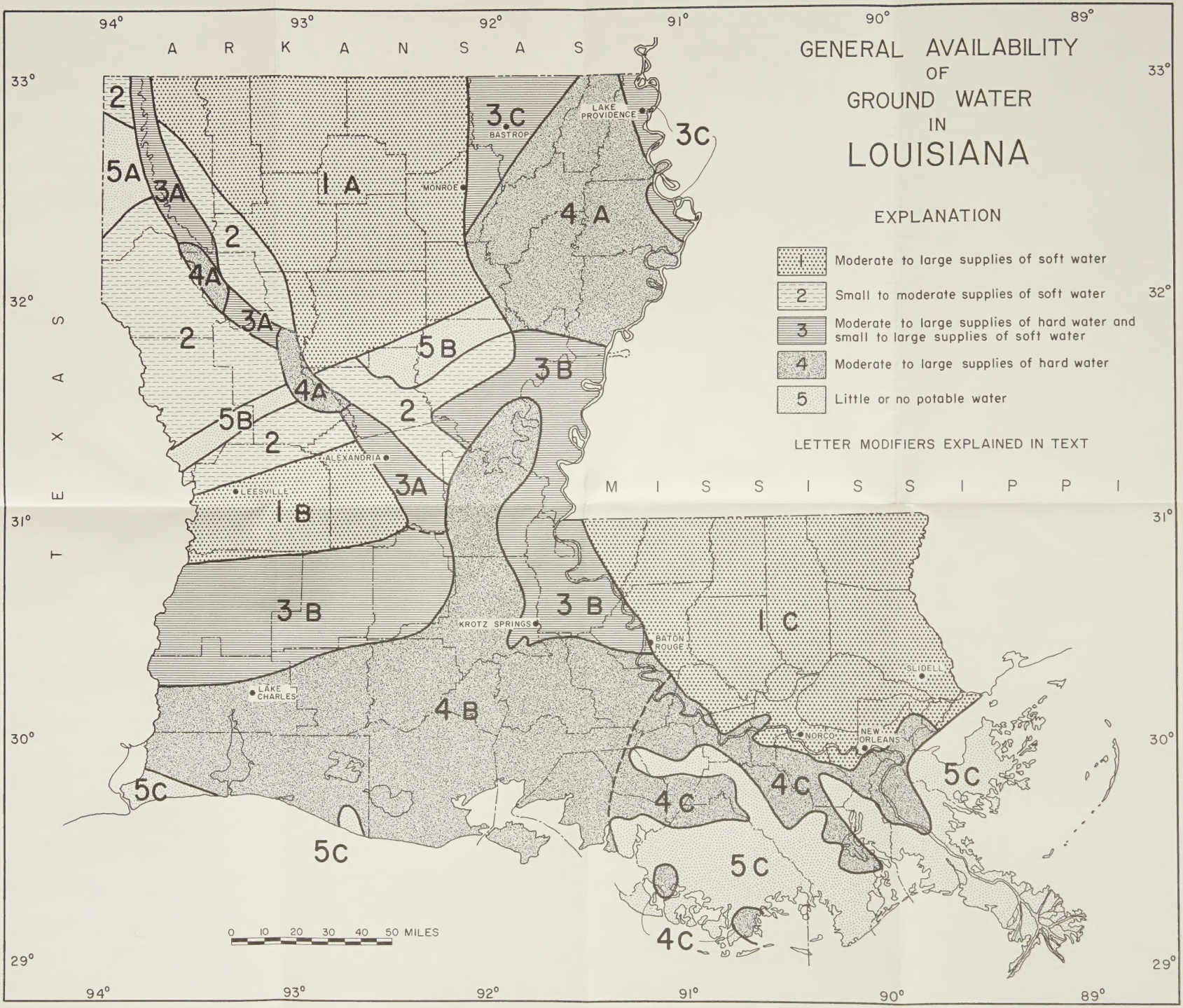
GENERAL AVAILABILITY
OF
GROUND WATER
IN
LOUISIANA
EXPLANATION
1 Moderate to large supplies of soft water
2 Small to moderate supplies of soft water
3 Moderate to large supplies of hard water and small to large supplies of soft water
4 Moderate to large supplies of hard water
5 Little or no potable water
LETTER MODIFIERS EXPLAINED IN TEXT
ARKANSAS
TEXAS
MISSISSIPPI
94°
93°
92°
91°
90°
89°
33°
32°
31°
30°
29°
MONROE
LAKE PROVIDENCE
BASTROP
ALEXANDRIA
LEESVILLE
KROTZ SPRINGS
BATON ROUGE
LAKE CHARLES
SLIDELL
NORCO
NEW ORLEANS
0 10 20 30 40 50 MILES